DUTY OF WATER INVESTIGATIONS

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DON H. BARK

IRRIGATION ENGINEER

IN CHARGE OF IRRIGATION INVE[illegible]IGATIONS IN IDAHO,
OFFICE OF EXPERIMEN[illegible]TIONS,
U. S. DEPARTMENT OF A[illegible]TURE.

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The Idaho State Board of Land Commissioners entered into a co-operative agreement with the Irrigation Investigations of the Office of Experiment Stations, U. S. Department of Agriculture, late in the fall of 1909 for the purpose of conducting a Duty of Water investigation in Idaho. This agreement was renewed from year to year, the investigation having been conducted uninterruptedly during the seasons of 1910, 11, 12, and 13. The agreement under which the investigation was carried on provided that both parties should contribute equal amounts toward the investigation; that the plans for the investigation be made and agreed upon by the Idaho State Engineer and the chief of Irrigation Investigations of the U. S. Department of Agriculture, and that the Idaho Agent of Irrigation Investigations should be charged with the carrying out of the investigation. The investigation has proved to be very popular with the irrigators of Idaho, eight of the larger irrigation companies of the State having contributed to the fund set aside for the purpose a total of almost $8,000.00 during the four years in order that the investigation might be extended. The reports of the investigation have also been much sought after, the demand during the past two years having far exceeded the available supply. The following report is based upon the results of the investigation during the four years, 1910 to 1913 inclusive, the investigation having covered the greater part of irrigated Idaho during the period.

"Duty of Water" is a term that is used to express the relationship that exists between a given quantity of irrigation water and the area of land it is made to serve. The Duty is said to be high when a given quantity of water serves a comparatively large area of land, and low when it is made to serve only a comparatively small area, *i. e.*, the Duty is the work the water is made to do. It is evident even to

those unfamiliar with irrigation that different types of land and different kinds of crops will require different amounts of water, and that all water rights should consist of amounts that would supply the actual requirements of the soils and crops in question and no more. The above is correct in theory, for the present area of arid land is fully twenty times that of the irrigated land, but to work it out in actual practice is a very difficult matter.

Forty years ago there was but litle irrigated land in Idaho, water was plentiful and the early settlers knew nothing of the water requirements of soils and crops. They therefore filed upon and appropriated abnormally large amounts for the irrigation of their land in order to be sure of a sufficient amount. As time passed and settlement increased a better knowledge of the water requirements of soils was obtained, but even as late as ten years ago there was no real definite knowledge of nor standard practice in regard to the subject. Water rights of all kinds and sizes existed. The need for definite knowledge of the proper amount of water to allot under different conditions became very urgent when the larger projects were proposed. It was realized that if too small an amount of water was allotted the settlers would suffer because of decreased crop production, while if more than enough was allotted the land would become water logged and useless from over irrigation and the ultimate irrigated area would be unnecessarily reduced. There had never been a broad and comprehensive investigation of this subject and the urgent need for this knowledge as a protection to the settlers and the State were the prime factors which led up to the investigation herein described.

GENERAL PLAN AND METHOD OF THE INVESTIGATION.

Previous investigations of the subject were few in number and rather confined in character. The majority of the investigations that had been made prior to the initiation of the investigation herein described were confined chiefly to the mere measurement of the amounts applied to crops by irrigation farmers and others. The various Western State Experiment Stations had also carried on some investigations of this subject but these investigations were necessarily confined to comparatively small areas on the

Experiment Station Farms. In laying plans for the present investigation it was plain to the author that if dependable data for use in connection with the allotment of water to large projects was to be secured (1) that an investigation of a broad character must be carried on; (2) that all of the various staple farm crops must be included; (3) that water must be measured upon rather large tracts; (4) that only such tracts as were typical as regards soil, topography, preparation of land, etc., should be included, for the ultimate results secured must be such as good farmers could obtain in actual practice; (5) that the mere measurement of water applied to a single tract and the yields secured from it would be insufficient data for they would throw no light upon the proper Duty, for there would be no indication as to what results might have been secured from the application of a larger or smaller quantity of water.

It seemed imperative that the investigation be conducted in such a way that the results would be practical, fair, and impartial, and that they could be used with safety in determining the irrigation requirements of a large project. It was realized that there was a great variation in soils and crops, and even between the irrigators themselves, as well as between different seasons, and it seemed plain that a large number of tracts should be included, and that the investigation be made to extend over a number of years if dependable data were to be secured.

It was therefore decided at the outset that the investigation should include all of the staple farm crops common to South Idaho, and that the water should be measured upon comparatively large areas. Tracts consisting of approximately 15 acres were fixed as a basis, care being used to select only such tracts as had uniform soil conditions, stand of crop, and previous preparation throughout. It was decided to include only typical tracts selected from average farmers' farms, and that each 15 acre tract, whenever possible, should be divided into three parts, that the farmer or owner should be allowed to select one of the three plots into which his tract was divided and to irrigate it during the season according to his own ideas, following his usual custom in regard to the time and amount of irrigation. The amount applied by the owner was to be measured very carefully by one of the author's assistants each time the land was irrigated, and the other two plots

were to be irrigated during the season by applying a greater amount to one and a less amount to the other than the owner used upon the plot which he himself had selected. Thus there were in almost every case three tracts of the same crop, each tract consisting of an area of about 5 acres with uniform soil conditions and previous preparation throughout, to which three different amounts of water were applied during the season. The water applied to and wasted from the tracts, the areas and yields, were all very carefully determined, and it was rather easy to decide in the fall from the yield produced which tract had received the best amount of water for the soil and crop in question. A portion of the experiments included in the investigation has been made at the Gooding Experiment Station, this station being conducted jointly by the Irrigation Investigations and the Idaho Experiment Station of the State Agricultural College.

Scope of Investigation.

The investigation has covered the seasons of 1910, 1911, 1912, and 1913, during which time water has been measured accurately upon a total of approximately 529 individual plots or tracts, ranging in size from .10 of an acre up to over 150 acres, and consisting of a total area of slightly over 3,600 acres. All of the areas involved have been carefully surveyed with a transit, and the measurement of the water applied to over two-thirds of the tracts experimented upon, has been made by our own assistants, who have been on the ground during the entire time of each irrigation. The water applied to the remainder of the tracts included in the investigation has been measured, (1) by automatic water registers, (2) by the owners themselves, or (3) by an assistant who, during the season of 1912, was employed to read a large number of weirs twice daily.

The results secured from a small proportion of the experiments have been found to be in error, due to accidents and a variety of other unavoidable circumstances. These have been discarded and nothing has been included in this report that is not absolutely dependable.

The investigation has covered a wide scope of territory, the experiments having been scattered from Weiser, with an altitude of 2,114 feet, situated on the bank of Snake River on the Oregon Line, to Rigby, with an altitude of 4,950 feet, in the upper Snake River Valley, 350 miles eastward from Weiser.

Alfalfa, clover, pasture, oats, wheat, barley, rye, potatoes and orchard, the staple crops of South Idaho, have all been represented, but the majority of the experiments have been conducted with alfalfa and the grains.

The average soil of South Idaho is a "lava ash" or medium clay loam, rich in lime and mineral plant foods, but deficient in nitrogen in its raw state. This soil ranges in depth from two to forty feet, with a probable average of slightly over four feet, and is well adapted for irrigation, being, as a rule, very uniform in texture and composition throughout its entire depth.

While the majority of the experiments have been conducted upon the average soil, the investigation has covered such a large number of tracts scattered over so wide an area that nearly all types of soil ranging from the finest of adobe clays to the coarsest of gravels have been well represented.

It was decided at the outset that the total amount of water that would be required by any project would depend upon the following factors:

(1) Gross area of project.

(2) Duty of water at the land.

(3) The amount of loss that the irrigation water would be subjected to in transmitting it from the point of diversion to the land to be irrigated.

(4) The amount of loss through both evaporation and seepage from reservoirs, if any were necessary in connection with the system.

(5) The proportion of a project that is ultimately irrigated.

It was therefore deemed necessary in connection with the investigation to investigate the seepage losses of typical Idaho canals and to survey a large amount of land included in well-developed typical irrigation projects to determine just what per cent was unirrigated. A seepage investigation was conducted during the two latter years of the investigation, 58 sections of different canals with an aggregate length of 109.2 miles having been measured in 1912, and 60 sections of different canals with an aggregate length of 178.11 miles having been measured during the season of 1913. The canals measured varied in discharge from 0.07 cu. ft. per second to over 3,190.0 cu. ft. per second, and in cross-section from 0.117 sq. ft. to 984.0 sp. ft.

The survey of irrigated land for the determination of the

percentage of waste and non-irrigated land in a typical project was conducted during the season of 1913. The land surveyed for this purpose consisted of a total of 16,065.21 acres, part of which was located near Kimberly, on the South Side Twin Falls Tract, the remainder lying under the old canals in the Boise River Valley adjacent to and tributary to the town of Meridian. The land surveyed was typical in every way of the better class of Idaho irrigated land and the results secured may be used with impunity as a basis for other or newer projects.

The investigation during the four years naturally and necessarily included the investigation of many other minor subjects, such as deep percolation on gravelly irrigated land, a study of rotation systems and their adaptability to different conditions, a study of the cost and feasibility of lifting water by electric motors and centrifugal pumps, and practically all other minor factors which it was believed might have a bearing on the duty of water.

Measurement of Water.

Cippoletti weirs were used for the measurement of all water applied to the experimental tracts throughout the investigation, carefully constructed weirs having been installed in the feed ditches leading to, and in the waste ditches leading from, each tract for the purpose. All of the amounts tabulated in this report represent only those retained upon, or absorbed by, the tract, the waste having been deducted, unless otherwise specified. In nearly all cases the measurements were made by assistants employed especially for the purpose, it having been decided for obvious reasons that it would be undesirable to have the owner, or anyone who might be prejudiced in favor of a high or low Duty, connected with the investigation in any way. The head on the weirs was measured by the assistant or assistants in charge of the experiments as often as was considered necessary. Where the head remained quite uniform it was measured at intervals of from one to two hours. Whenever the amount of water and consequent head on the weirs varied or fluctuated to any extent the head was measured more frequently.

The Cippoletti weir, designed by the Italian engineer of the same name, was used exclusively throughout the investigation, great care being used to secure the proper conditions for accurate measurement. The formula used in

computing the discharge of these weirs was Q equals 3.367 L. H. $\frac{3}{2}$

Where Q equals discharge in cubic feet per second,
L equals length of crest in feet, and
H equals head or depth of water on the crest in feet.

The above is the formula used in general practice for the determination of the discharge over this type of weir and, provided certain conditions are maintained, has been determined to be within one per cent of accurate by many long series of complicated experiments.

The conditions which must obtain to insure reasonable accuracy of measurement, and which, as near as possible, were observed throughout the investigation, are:

(1) The weir proper should consist of a notch, trapezoidal in shape and thin in section, preferably cut from a piece of metal such as sixteen gauge galvanized iron.

(2) The bottom edge of the notch should be a straight line either one, two, or three feet in length, or longer, depending upon the amount of water required, which should govern the size of the weir. The sides of the notch should slope outward at the rate of one horizontally to four vertically, thus a one foot Cippoletti weir should have a bottom or crest length of exactly one foot and a top width, with a depth of six inches, of fifteen inches, both sides of the weir sloping outward at the same angle.

(3) All water to be measured should be passed through the notch or over the weir. The notch or weir must be set vertically with its crest or bottom in a horizontal position, and the entire plate or notch should be perpendicular to the axis of the stream.

(4) The water should have a free fall over the weir, *i. e.,* the water below the weir should not back up so as to drown or submerge it. There should be enough clearance so that air can circulate freely under the issuing stream at all times.

(5) The water should enter the weir slowly, being brought to a state of rest if possible before entering or passing over the weir. This is usually secured by digging a rather deep, wide pool above the weir or by building the weir box of large enough cross section to insure a slow "velocity of approach," which is very necessary if accurate measurement is to be obtained.

(6) The depth of water flowing over the crest of the

weir should not be measured on the crest but from a point level with the crest and up-stream from it, a distance of about twice the length of the crest. This is necessary, as the water has a downward curve as the crest is approached, and the depth must be measured from still water if the formula is to give accurate measurement. The best and most common method of setting a point from which to measure the water, and the one that was used throughout the investigation, is to set a heavy 2x4 or 4x4 peg or stake in the pool up-stream from the weir. This peg should be heavy enough so that it cannot be readily disturbed, and should be driven from one-half to an inch below the level of the weir crest. A heavy nail or spike should then be driven vertically into the top of the stake, the upper face of the spike being exactly levelled with the crest of the weir by means of a carpenter's or engineer's level, the weir having previously been established in the weir box both vertical and horizontal and at right angles to the axis of the stream entering the weir box.

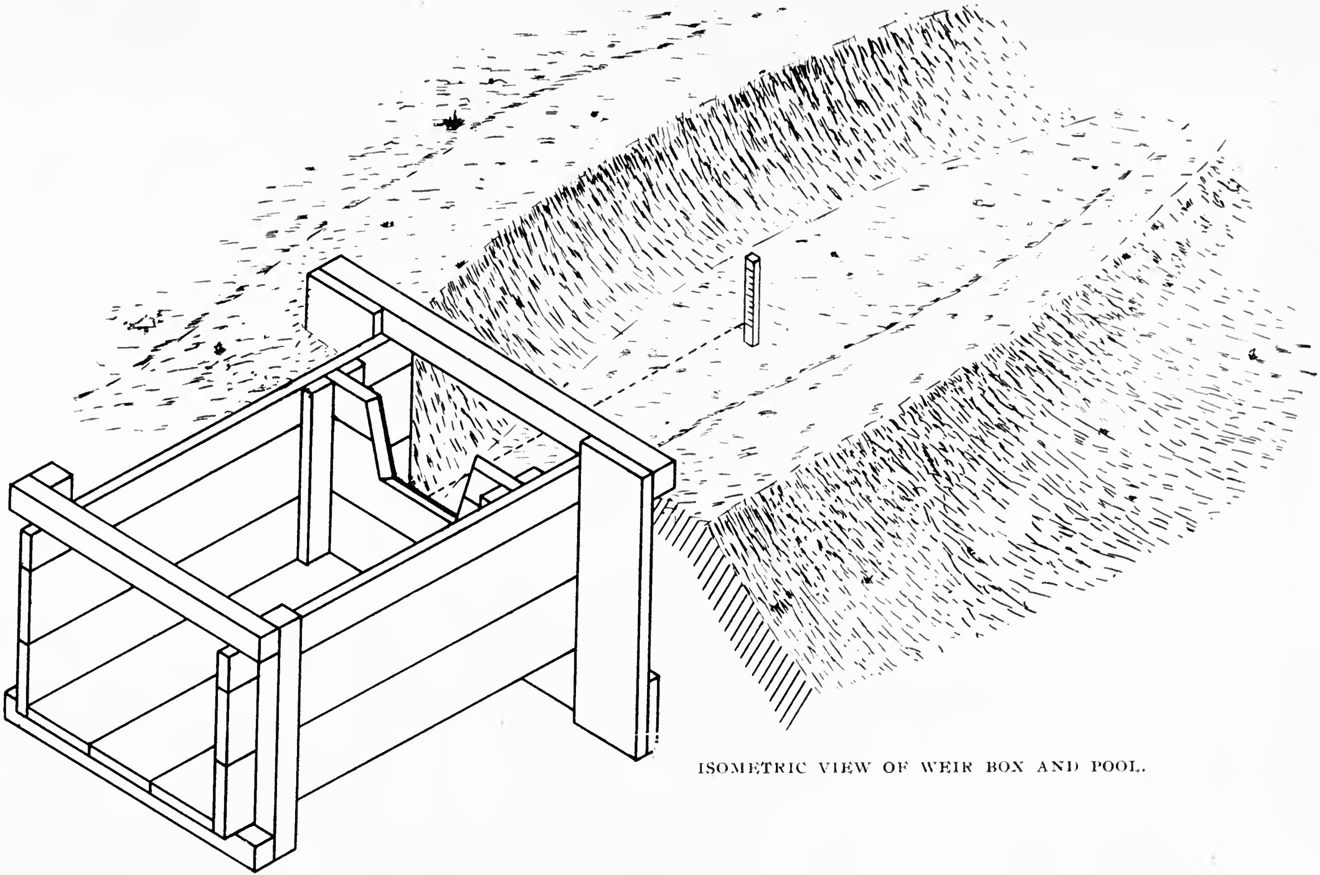
The head on the weirs was measured by the observers with small steel rules graduated to one-hundredth of a foot. During measurement the observer held his eye as close to the surface of the water in the pool as possible and extended the thin rule down through the water to the head of the nail, the height of the water on the rule being noted, which gave the correct head on the weir.

(7) The depth of water flowing over the crest should never be allowed to exceed one-half of the crest length, and it is preferable that it should not exceed one-third of the crest length. Where it is desired to measure so much water that it gives too great a depth on a one-foot weir, a two-foot weir or a three-foot weir, as the case may be, should be installed. Accurate measurement demands that there should never be less than one inch of water flowing over the crest. This is necessary in order to secure complete contraction of the issuing stream, which is very essential. Obstructions of any kind should not be permitted. The sides of the weir box or pool should never approach the sides of the weir. The distance between the edge of the issuing stream and the outer edge of the box for small weirs should always be at least twice as great as the depth of water flowing over the crest.

It has been determined by experiment that the following conditions are necessary if a slow velocity of approach is to

be secured on weirs. These conditions are not ironclad, however, and may be varied slightly, the slow velocity of approach and an unobstructed free fall of the issuing stream being the things most of all desired. The cross section of the stream in the weir box or in the pool above the weir should be at least seven times as great as that of the stream which issues through and over the weir crest. The height of the crest above the bottom of the box or pool should be at least twice and preferably three times that of the depth of the water over the crest.

In order to better illustrate the conditions that must obtain for accurate measurement and the conditions that were observed throughout the Duty of Water investigation, the following cut of an ideal weir and weir box are inserted:



ISOMETRIC VIEW OF WEIR BOX AND POOL.

The weir box shown in the above cut is no part of the weir proper and is necessary for the sole and only purpose of holding the weir in place and forcing all of the water to pass over it without leakage. Some writers insist on longer boxes or boxes of specific dimension, but these dimensions have been arrived at and are given in order to insure a sufficient size of cross section to insure free fall over the weir, complete contraction of the issuing stream, and a slow velocity of approach. The above canditions may be obtained, including a slow velocity of approach, if the foregoing instructions are carefully observed, and a comparatively deep, wide pool is maintained in the ditch above the weir box.

The following table has been compiled for the use of irrigation farmers and others, the depths on the crest being given in inches and fractions of an inch rather than in hundredths of a foot in order that the irrigators may use the table in connection with the ordinary rules in common use, such as school rulers, yard sticks, carpenter's rules, or squares instead of special rules graduated to hundredths of a foot, which are not commonly accessible. This table gives the discharge over the smaller sizes of weirs both in cubic feet per second and in Idaho miner's inches, of which there are fifty in a "second foot."

DISCHARGE OF CIPPOLETTI WEIRS IN IDAHO MINER'S INCHES AND SECOND FEET.

Depth of water on crest —inches	One-foot weir		Two-foot weir		Three-foot weir	
	Second feet	Miner's inches	Second feet	Miner's inches	Second feet	Miner's inches
¼	.010	0.5	.020	1.0	.030	1.5
½	.029	1.5	.058	2.9	.087	4.4
¾	.053	2.7	.106	5.3	.159	8.0
1	.081	4.1	.162	8.1	.243	12.2
¼	.113	5.7	.226	11.3	.339	17.0
½	.149	7.5	.298	14.9	.447	22.4
¾	.188	9.4	.376	18.8	.564	28.2
2	.229	11.5	.458	22.9	.687	34.4
¼	.273	13.7	.546	27.3	.819	41.0
½	.320	16.0	.640	32.0	.960	48.0
¾	.369	18.5	.738	36.9	1.107	55.4
3	.421	21.1	.842	42.1	1.263	63.2
¼	.474	23.7	.948	47.4	1.422	71.1
½	.530	26.5	1.060	53.0	1.590	79.5
¾	.588	29.4	1.176	58.8	1.764	88.2
4	.648	32.4	1.296	64.8	1.944	97.2
¼	.709	35.5	1.418	70.9	2.127	106.4
½	.773	38.7	1.546	77.3	2.319	116.0
¾	.839	42.0	1.678	83.9	2.517	125.9
5	.906	45.3	1.812	90.6	2.718	135.9
¼	.974	48.7	1.948	97.4	2.922	146.1
½	1.044	52.2	2.088	104.4	3.132	156.6
¾	1.116	55.8	2.232	111.6	3.348	167.4
6	1.191	59.6	2.382	119.1	3.573	178.7
¼	....	....	2.531	126.6	3.796	189.8
½	....	....	2.684	134.2	4.026	201.3
¾	....	....	2.841	142.1	4.261	213.1
7	....	....	3.000	150.0	4.500	225.0
¼	....	....	3.162	158.1	4.743	237.1
½	....	....	3.327	166.4	4.990	249.5
¾	....	....	3.496	174.8	5.244	262.2
8	....	....	3.664	183.2	5.496	274.8
¼	....	....	3.838	191.9	5.757	287.9
½	....	....	4.014	200.7	6.021	301.1
¾	....	....	4.192	209.6	6.288	314.4
9	....	....	4.374	218.7	6.561	328.0
¼	....	....	4.557	227.9	6.835	341.8
½	....	....	4.744	237.2	7.116	355.8
¾	....	....	4.932	246.6	7.398	369.9
10	....	....	5.124	256.2	7.686	384.3
¼	....	....	5.316	265.8	7.974	398.7
½	....	....	5.510	275.5	8.265	413.3
¾	....	....	5.709	285.5	8.563	428.2
11	....	....	5.910	295.5	8.865	443.2
¼	....	....	6.112	305.6	9.168	458.4
½	....	....	6.317	315.9	9.475	473.9
¾	....	....	6.525	326.3	9.787	489.4
12	....	....	6.734	336.7	10.101	505.0

The above table gives the discharge of the smaller sizes of Cippoletti weirs in cubic feet per second and in Idaho miner's inches, but is not of much use to the ordinary irrigator in determining the exact depth or quantity that he has applied to his land in acre feet. For the use of those who care to calculate the amounts that have been applied either as acre feet or as depths on the land, the following table is included, it having been devised to facilitate the enormous amount of computation in connection with the four seasons' Duty of Water Investigation. From it

may be obtained the number of acre feet or fraction of an acre foot per hour that will be discharged over the smaller sizes of Cippoletti weirs such as will be used in common practice. In illustration of its use it will be seen from the table that a depth of three inches or 0.25 feet over a one foot Cippoletei weir will discharge .0348 acre feet per hour, or .348 acre feet in ten hours, or 3.48 acre feet in one hundred hours, which would cover one acre 3.48 feet deep in 100 hours.

DISCHARGE OF CIPPOLETTI WEIRS IN ACRE FEET PER HOUR.

Depth of water on crest—feet	Acre feet in one hour			Depth of water on crest—feet	Acre feet in one hour			Depth of water on crest—feet	Acre feet in one hour		Depth of water on crest—feet	Acre feet in one hour	
	1-ft weir	2-ft weir	3-ft weir		1-ft weir	2-ft weir	3-ft weir		2-ft weir	3-ft weir		2-ft weir	3-ft weir
.01	.0003	.0006	.0008	.26	.0369	.0738	.1107	.51	.2027	.3040	.76	.3687	.5530
.02	.0008	.0016	.0024	.27	.0390	.0781	.1171	.52	.2087	.3130	.77	.3760	.5640
.03	.0014	.0029	.0043	.28	.0412	.0824	.1237	.53	.2147	.3221	.78	.3833	.5750
.04	.0022	.0045	.0067	.29	.0435	.0869	.1304	.54	.2208	.3312	.79	.3907	.5861
.05	.0031	.0062	.0093	.30	.0457	.0914	.1372	.55	.2270	.3405	.80	.3982	.5973
.06	.0041	.0082	.0123	.31	.0480	.0960	.1441	.56	.2332	.3498	.81	.4057	.6085
.07	.0052	.0103	.0155	.32	.0504	.1007	.1511	.57	.2395	.3592	.82	.4132	.6198
.08	.0063	.0126	.0189	.33	.0527	.1055	.1582	.58	.2458	.3687	.83	.4208	.6312
.09	.0075	.0150	.0225	.34	.0552	.1103	.1655	.59	.2522	.3783	.84	.4284	.6426
.10	.0088	.0176	.0264	.35	.0576	.1152	.1728	.60	.2586	.3879	.85	.4361	.6541
.11	.0102	.0203	.0305	.36	.0601	.1202	.1803	.61	.2651	.3977	.86	.4438	.6657
.12	.0116	.0231	.0347	.37	.0626	.1252	.1879	.62	.2717	.4075	.87	.4516	.6774
.13	.0130	.0261	.0391	.38	.0652	.1304	.1955	.63	.2783	.4174	.88	.4594	.6891
.14	.0146	.0291	.0437	.39	.0678	.1355	.2033	.64	.2849	.4274	.89	.4672	.7008
.15	.0162	.0323	.0485	.40	.0704	.1408	.2112	.65	.2916	.4374	.90	.4751	.7127
.16	.0178	.0356	.0534	.41	.0730	.1461	.2191	.66	.2984	.4476	.91	.4831	.7246
.17	.0195	.0390	.0585	.42	.0757	.1515	.2272	.67	.3052	.4578	.92	.4911	.7366
.18	.0212	.0425	.0637	.43	.0785	.1569	.2354	.68	.3120	.4681	.93	.4991	.7486
.19	.0230	.0461	.0691	.44	.0812	.1624	.2436	.69	.3189	.4784	.94	.5072	.7607
.20	.0249	.0498	.0747	.45	.0840	.1680	.2520	.70	.3259	.4889	.95	.5153	.7729
.21	.0268	.0536	.0803	.46	.0868	.1736	.2604	.71	.3329	.4994	.96	.5234	.7851
.22	.0287	.0574	.0861	.47	.0897	.1793	.2690	.72	.3400	.5100	.97	.5316	.7974
.23	.0307	.0614	.0921	.48	.0925	.1851	.2776	.73	.3471	.5206	.98	.5399	.8098
.24	.0327	.0654	.0981	.49	.0954	.1909	.2863	.74	.3542	.5314	.99	.5481	.8222
.25	.0348	.0696	.1043	.50	.0984	.1967	.2951	.75	.3614	.5422	1.00	.5565	.8347

Unit of Measurement.

The miner's inch was the first common unit of measurement of flowing water in nearly all of the Western States, the system or method having been evolved by the early placer miners for the measurement of the water to which they were entitled. Though this unit and method of measurement was fairly well adapted for the use of the miners in the measurement of the small streams, the unit is rather indefinite and intangible and the method of measurement is cumbersome and not adapted to the measurement of large streams such as are now being used for irrigation purposes. The miner's inch was the amount of water that would

flow through a sharp edged orifice one inch square under a given pressure. The pressure and consequent size of the miner's inch varied in different States, which resulted in considerable confusion. An Idaho miner's inch is the amount of water that will flow through a sharp, thin edged orifice one inch square with a pressure of four inches over the center of the opening. An Idaho miner's inch happens to equal txactly nine gallons per minute.

Second Foot.

A much better unit and method of measurement, and one which is adapted to streams of all sizes and descriptions, has now been evolved. It is definite and more easily understood, but it is hard to make the old time irrigators forget the old method and adopt the new one, and this is being only gradually accomplished. The newer unit of measurement, and the one that is the best that has been yet devised for the measurement of all sizes of streams of flowing water, is the cubic foot per second, which simply represents what the term itself signifies, *i. e.*, a cubic foot of water each second of time, it only being necessary to determine the area of the cross section of a stream in square feet and the average velocity in feet per second, which two factors multiplied together give the correct discharge of the stream in cubic feet per second. The cubic foot per second is now the legal standard for the measurement of flowing water in Idaho, it having been adopted by the Idaho Legislature in 1899. The cubic foot per second (commonly known as the "second foot") represents a flow of water which will exactly fill a vessel containing one cubic foot each second of time for as long a period as it is allowed to flow; hence a flow of one cubic foot per second delivers 60 cubic feet per minute, or 3,600 cubic feet per hour, or 86,400 cubic feet in a day of twenty-four hours. A flow of one cubic foot per second equals almost exactly fifty Idaho miner's inches or 450 gallons per minute. One Idaho miner's inch, therefore, equals a flow of nine gallons per minute.

Acre Foot.

Where large volumes of water are to be considered the expression of the amount in cubic feet would involve the use of such large numbers that the same would be cumbersome. In order to simplify these expressions the term

"acre foot" is used. An acre foot represents enough water to cover an acre one foot in depth, or 43,560 cubic feet. The use of this term has the additional advantage of being easily compared with the acreage, as, for example, a reservoir containing 50,000 acre feet of water would furnish a depth of two feet for 25,000 acres of land. A cubic foot of water per second flowing continuously for twenty-four hours furnishes almost exactly twenty-four acre inches or two acre feet of water. Hence a continuous flow of one cubic foot per second will cover an acre one inch deep in one hour, or two inches in two hours, or four acres three inches deep in twelve hours.

It has been customary to express the Duty on any project as a certain fraction or number of miner's inches per acre, or the number of acres served by a continuous flow of a cubic foot per second. The expression of the Duty in this manner, however, is rather impractical and too indefinite for experimental purposes, for the total amount of water applied depends not only upon the size of the stream used per acre and whether or not it has flowed continuously, but upon the length of the irrigation season as well. In order to eliminate all variable elements and make all results strictly comparable, the amounts that have been applied and retained on the soil in this investigation are herein tabulated as acre feet per acre, or depths of application on the land, these two expressions being equivalent. The results have thus been made strictly comparable and should be easily understood.

Hydraulic Equivalents Which Will Be Found Useful to Irrigators.

In order to throw additional light on the various terms used in this report and to allow ready comparison of the different units, the following hydraulic equivalents are inserted:

1. One Idaho miner's inch equals approximately one-fiftieth of a cubic foot per second, or 9 gallons per minute.
2. A cubic foot per second equals approximately 50 Idaho miner's inches, or 450 gallons per minute.
3. One cubic foot per second for 24 hours equals approximately 2 acre feet, or one acre inch per hour.
4. One acre foot equals enough water to cover an acre exactly one foot in depth, or 43,560 cubic feet.

5. One miner's inch per acre for 100 days equals 3.97 feet deep on the land.

6. One miner's inch per acre for 150 days equals 5.95 feet deep on the land.

7. five-eighths miner's inch per acre for 100 days equals 2.48 feet deep on the land.

8. Five-eighths miner's inch per acre for 150 days equals 3.72 feet deep on the land.

9. One-half miner's inch per acre for 100 days equals 1.98 feet deep on the land.

10. One-half miner's inch per acre for 150 days equals 2.98 feet deep on the land.

Determination of Areas and Yields.

The areas of all experimental plots and tracts included in the investigation, with the exception of the areas contained in the large projects, have been determined by actual surveys with a transit and chain. The surveys were carefully plotted in the office to a scale of 100 feet to the inch, the areas being determined by the use of a polar planimeter. It is believed that the areas of all experimental tracts of a smaller size than 160 acres, as tabulated herein, are accurate to within one-hundredth of an acre.

The yields produced have been weighed whenever possible. In other cases, where the farms were located at long distances from a set of scales, the yields of hay have been computed in the stack by the approved rules used in common practice. The yields from the different experimental tracts were invariably cut, threshed and stacked separately, extreme care being used at all times to avoid error. Though the determination of the yields of the hay, where weighing has been impractical, may have been slightly inaccurate, it is certain that they are comparable, in which case the value of the experiments have not been vitiated in any way.

Soil Classification.

A careful classification of the soil from each tract experimented upon to a depth of at least four feet has been made in the field by means of a sufficient number of test pits in various parts of each field to determine with a fair amount of accuracy the character of the soil experimented upon. Chemical analyses of the soil have been made in but few cases. Typical samples of the first, second, third,

and fourth feet of the soil from each tract experimented upon have been secured and are now filed away for further reference. It is regretted that the enforced brevity of this report will not permit of a detailed description of the soil of each tract, for it has been found that the Duty depends upon the character of the soil more than upon any other one thing.

Moisture Determination.

In view of the wide scope of territory included in the investigation it was deemed necessary to determine the amount of moisture that existed in the soils of the experimental tracts by reason of winter precipitation, previous irrigation, seepage, etc., on or about the time crops were planted or began their growth in the spring. A careful determination of the per cent of moisture in the firse, second, third and fourth feet of soil of each tract has therefore been made. These determinations have been of material assistance in comparing the various results secured, for some tracts have been found to contain twice as much moisture at planting time as others. Except at the permanent experiment stations conducted by the state and the government it has been impossible on account of lack of time and funds to make a determination of the moisture in the soils at the end of the irrigation season, although this would have been very desirable.

Reimbursement of Loss.

It has been necessary in but few cases to enter into written contracts with the owners of the tracts experimented upon, for the irrigation farmers of Idaho have almost without exception been glad to co-operate in the investigation. It has been necessary, however, to make reimbursment to the owners for crop shortage occasioned by the variation of the water. The yield made on the tract handled by the owner has been used as the basis for such settlements. Reimbursement of the owners has been found necessary in only about one-third of the cases but had it been possible to induce the owners of the tracts experimented upon to reimburse the state in those cases where the yield was increased by reason of the water variation there would have been no fund required for reimbursement of loss.

Measurement of Use of Water With Water Registers.

The usual method of procedure throughout the investi-

gation was to detail one assistant to four or five fifteen-acre tracts upon as many farms in the same neighborhood. This assistant devoted his entire time and attention during the season to the measurement of water and the detail work in connection with the four or five experimental tracts, each of which was divided into three approximately equal parts. This method of procedure was rather expensive in that one assistant could not cover much territory during the season. In order to broaden the investigation and determine the normal use of water by the farmers the water applied to a comparatively large area was measured each season by automatic water registers, which were installed for the purpose on the weirs in the head ditches leading to the tracts in question. Each of these water registers would measure accurately, with but little attention, the amount applied during the season to tracts varying in size from fifteen to one hundred and fifty acres. The investigation has in this way been broadened considerably over what it would have been had all water been measured by assistants employed for the purpose. The water applied to by far the majority of the tracts included in the investigation has been measured by men employed for the purpose, but the area served by the water registers was nearly, if not quite, equal to that measured by the men themselves.

Weather Conditions.

It has not been possible or practical to install a rain gauge in connection with each experimental tract included in the investigation. The Weather Bureau of the U. S. Department of Agriculture has numerous co-operative observer stations scattered quite uniformly throughout the territory involved. The precipitation that has occurred upon the experimental tracts has been assumed to be equal to that of the United States Weather Bureau Station nearest the tract in question. While it is known that this may vary a small per cent from accuracy, it is considered that the slight differences that may have existed can be safely neglected. Any peculiarities of weather, such as excessive or deficient precipitation, or early or late frosts, have been carefully noted and taken into consideration when arriving at conclusions in regard to any of the experiments.

The growing season of 1910 in Idaho was the dryest on

record. The precipitation during seven consecutive months from March to September inclusive was below normal. The temperature ranged above normal during almost the entire season. The seasons of 1911 and 1912 were quite similar to one another and averaged much cooler than that of 1910. The precipitation during both 1911 and 1912, however, ranged above normal during the growing season, as may be seen from the tables which follow.

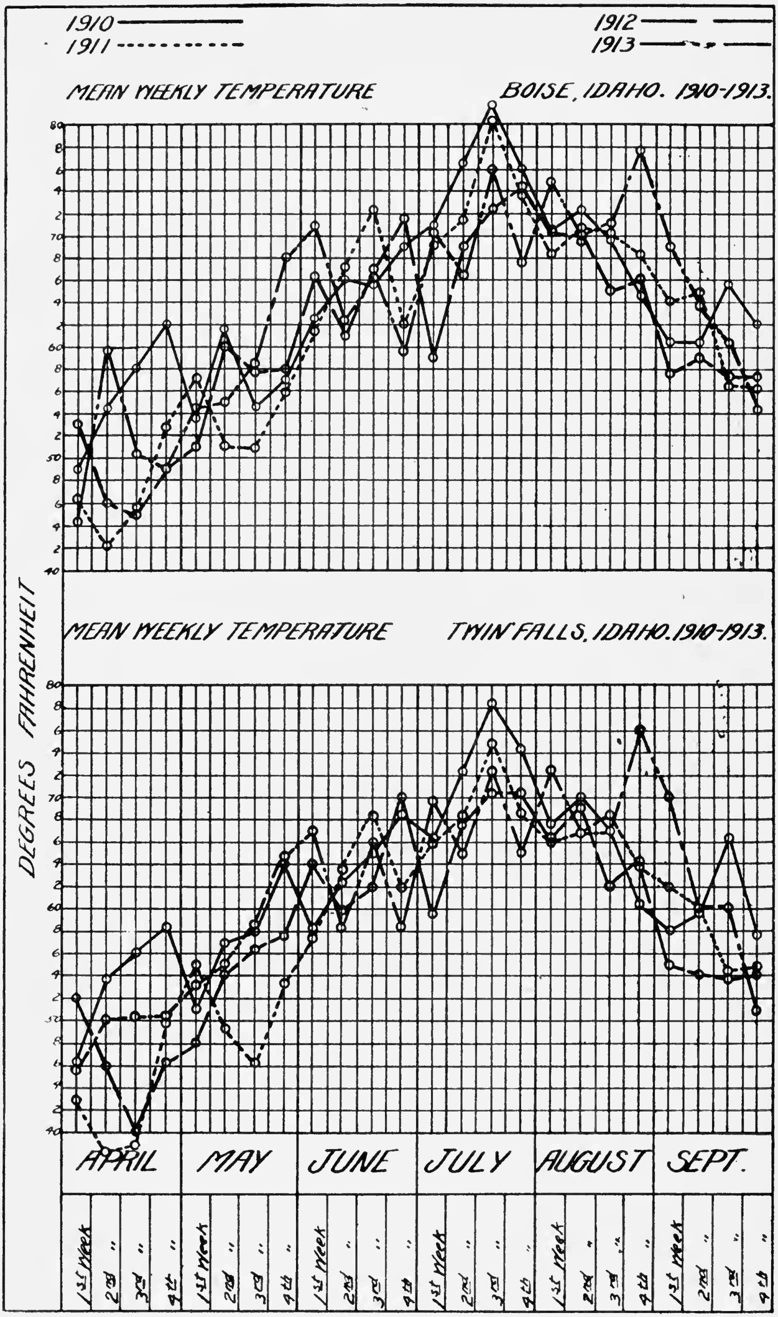
The season of 1913 was another with high precipitation, the precipitation averaging above normal for the six growing months at Boise, Buhl, Hollister, Idaho Falls, Oakley and Twin Falls, Gooding being the only place under investigation where the precipitation was below normal. The temperature during the season of 1913 was a fair average of that of the other three years, 1910 to 1912 inclusive, with the exception that the fourth week of August instead of the third week of July was the hottest week of the year, the third week in July having been the hottest week for three consecutive years at all of the places included in the investigations. June of 1913, at all stations, was a very cool month, an unusual amount of precipitation having fallen during the month.

Considering the weather conditions during the four years as a whole, as one can do with considerable detail from the following charts and tables, it would seem that the investigation covered enough different years with their varied climatic conditions to insure accuracy and fairness in the average results that have been obtained.

The following tables and charts have been compiled from the records of the United States Weather Bureau for the purpose of showing in condensed form the weather conditions that existed during the four years covered by the investigation. The temperature chart giving the range of temperature during the four growing seasons has been made to include only Boise and Twin Falls. These two points are quite widely separated, but both are in the midst of large irrigated areas in which rather complete investigations have been made and a fair idea of the temperature range may be gained from them.

Precipitation in Inches.

Locality	Length of record—years	Average precipita'n		Monthly Precipitation						Total for six months	Per cent of normal
		Annual	6 months April to Sept.	April	May	June	July	August	Sept.		
Season of 1910											
Blackfoot........	14	10.46	4.66	0.67	0.78	0.10	0.21	T	0.47	2.23	48
Boise..............	25	12.71	4.10	1.10	1.14	0.30	T	0	0.50	3.04	74
Buhl..............	3	12.22	5.13	0.82	0.55	0.25	0.28	0	......	......	......
Caldwell..........	5	10.54	3.51	1.05	0.84	0.03	T	0	0.89	2.81	80
Gooding..........	1	......	......	0.77	0.32	0.08	0.24	0	0.44	1.85	.....
Hailey............	8	17.15	4.04	0.81	0.80	0.06	0.27	0	1.33	3.27	81
Idaho Falls......	15	14.44	6.00	0.06	0.75	0.14	0.11	T	1.30	2.36	39
Shoshone.........	3	15.06	2.91	0.33	0.43	0.01	0.18	0	0.54	1.49	51
Twin Falls......	5	12.90	4.40	0.73	0.52	0.06	0.12	T	0.95	2.38	54
Season of 1911											
Boise..............	26	12.71	4.10	1.59	2.57	2.55	0.05	T	0.04	6.80	166
Buhl..............	4	11.15	5.17	0.86	1.97	2.34	0.18	T	T	5.35	103
Caldwell..........	6	10.31	3.59	1.03	1.13	1.44	0.23	T	0.12	3.95	110
Gooding..........	2	9.40	3.20	1.15	1.77	1.06	0	0	T	3.98	124
Hailey............	9	16.27	4.30	1.67	2.91	1.53	0.04	T	0.03	6.18	144
Idaho Falls......	16	14.00	6.06	0.95	2.29	2.67	0.30	0.07	0.67	6.95	115
Oakley............	18	9.58	4.68	0.15	1.75	2.76	0.84	0	0.30	5.80	124
Twin Falls......	6	12.10	4.19	0.43	1.74	0.83	0.05	0.04	0.10	3.19	76
Wendell..........	3	13.86	3.96	1.35	2.00	1.95	T	0	T	5.30	134
Season of 1912											
Boise..............	27	12.71	4.10	3.34	1.94	0.86	1.27	0.07	0.77	8.25	201
Buhl..............	5	10.90	4.99	1.92	0.43	0.90	0.18	0.08	0.30	3.81	76
Caldwell..........	7	10.05	4.13	1.96	2.05	1.77	1.22	0.21	0.53	7.74	18[illegible]
Gooding..........	3	10.82	3.24	0.96	1.33	0.67	0.33	T	0.18	3.47	107
Idaho Falls......	17	14.23	6.19	1.94	1.36	0.89	1.60	2.28	0.44	8.51	137
Twin Falls.......	7	11.98	4.13	1.68	0.63	0.46	0.48	0.16	0.30	3.71	90
Wendell..........	4	13.76	3.82	1.38	0.57	0.86	0.04	T	0.31	3.16	83
Season of 1913											
Boise..............	28	12.71	4.10	0.95	0.58	1.64	2.01	0.03	0.65	5.86	143
Buhl..............	7	11.25	5.25	0.62	1.58	2.49	2.29	0.13	0.05	7.16	136
Gooding..........	4	11.14	3.04	0.47	0.15	0.91	0.73	0.08	0.05	2.39	79
Hollister.........	2	12.97	6.74	0.89	1.79	2.40	1.65	0.13	0.49	7.35	109
Idaho Falls......	18	14.35	6.32	0.35	2.39	2.99	1.86	0.08	0.88	8.55	135
Oakley............	19	9.99	5.04	0.15	1.36	3.01	1.85	0.84	0.65	7.86	15[illegible]
Rogerson.........	.....	......	......	......	1.25	4.32	1.29	1.17	......	......	......
Twin Falls......	8	11.78	4.54	0.53	0.75	2.54	1.50	0.17	2.09	7.58	167


1910
1911
1912
1913
MEAN WEEKLY TEMPERATURE
BOISE, IDAHO. 1910-1913.
MEAN WEEKLY TEMPERATURE
TWIN FALLS, IDAHO. 1910-1913.
DEGREES FAHRENHEIT
APRIL
MAY
JUNE
JULY
AUGUST
SEPT.
1st Week
2nd "
3rd "
4th "

Method of Interpreting Results.

The correct and proper analysis of the results that have been secured has been the most difficult part of the entire investigation. There are so many factors other than mere amount of water application that might influence the yields that have been secured from the experimental tracts that the proper interpretation of the results has indeed been a difficult problem. It has been plain that under normal conditions the tract producing the best yield has had the best application of water for the soil and crop in question. In some cases, however, the largest yield has exceeded the yield of one of the other two tracts by less than 5 per cent, yet the amount of water applied might have exceeded that applied to the second tract by as much as 100 per cent. In such cases it has been plain if economy of time and water are to be considered that the tract making the smaller yield was handled more economically.

The investigation as a whole has made it plain that a single experiment is not dependable, because of the insidious variations that sometimes unavoidably creep in. There have sometimes been great variations in the yields produced by the same amount of water on the same crop upon adjoining farms during the same season. It became evident beyond contradiction early in the investigation that the results secured from a large number of tracts consisting of a considerable area were the only data that would be found dependable; also that an average of the data secured during as many years as possible was the most dependable for in no other way could the peculiarities of the individual tracts or the seasonal variations in the climate be neutralized.

It was found early in the investigation that the various crops naturally formed themselves into two groups: (1) those requiring the least water; and (2) those requiring the most water. The grains, both spring and winter, potatoes, and clean cultivated orchards were found to lie in group No. 1, while alfalfa, the clovers and pasture were found to lie in group No. 2, the crops in the second group requiring nearly twice as much water as the crops in group No. 1. The following tables have been compiled and give in a condensed form a brief resume of the experiments that have been conducted. The crops are grouped in the tables according to their water requirements into groups No. 1 and No. 2. It is to be regretted that the enforced

brevity of this report will not permit of even a brief detailed description of each experiment, the space allotted to each experiment in the tables which follow being the only detailed description of each experiment that can be included. These tables show, (1) the kind of crop, (2) the altitude, (3) a brief description of the class of soil, (4) the area of each tract experimented upon, (5) the precipitation recorded at the nearest Weather Bureau Station, (6) the date of the first irrigation during the season, (7) the length of the irrigation season in days, (8) the number of irrigations that were applied during the season, (9) the total depth of irrigation water that was applied and retained upon the tract in question, all waste water having been deducted, unless otherwise specified, and (10) the yields that were secured per acre. For convenience the results from the three or more plots on each farm are grouped together, the experiments on the different farms being separated slightly in the tables. The readers are requested to bear in mind that the "total depth applied" includes only the irrigation water that was retained upon the tract in question, the rainfall during the season being given in another column.

Table Showing Effects of Using Different Amounts of Water on Grains, Alfalfa, Etc., in Idaho, During the Seasons of 1910-11-12-13.

Number	Kind of crop	Altitude	Class of soil	Area —acres	In. precipitation Apr. to Sep. inc.	Date of first irrigation	Ir. season—days	No. of irrigat'ns	Total depth irrigation water applied—feet	Yield per acre
	Grain—1910									
1	Oats	3968	Slightly Sandy Loam...	3.91	1.49	5-31	63	3	2.12	22.8 bu
2	Oats	3968	Slightly Sandy Loam...	3.73	1.49	5-31	75	4	2.20	27.7 bu
3	Oats	3968	Slightly Sandy Loam...	4.51	1.49	5-31	87	5	3.31	27.6 bu
4	Wheat	3800	Medium Clay Loam......	4.95	.....	6-5	...	1	.87	44.5 bu
5	Wheat	3800	Medium Clay Loam......	5.06	.....	5-26	27	2	1.44	67.2 bu
6	Wheat	3800	Medium Clay Loam......	5.06	.....	5-24	28	3	2.20	59.3 bu
7	Wheat	4949	Very Gravelly...........	4.96	2.36	6-9	77	4	2.40	10.0 bu
8	Wheat	4949	Very Gravelly...........	4.94	2.36	6-9	78	4	2.26	11.1 bu
9	Wheat	4949	Very Gravelly...........	4.79	2.36	6-10	77	4	2.26	11.3 bu
10	Oats	4949	Very Gravelly...........	2.93	2.36	6-3	54	4	3.26	22.0 bu
11	Wheat	4949	Very Gravelly...........	4.02	2.36	6-5	54	3	3.70	24.3 bu
12	Wheat	4949	Very Gravelly...........	4.98	2.36	6-5	54	4	4.73	32.7 bu
13	Wheat	4949	Very Gravelly...........	4.93	2.36	6-4	53	5	7.08	30.2 bu
14	Wheat	4949	Gravelly Clay............	3.60	2.36	6-10	31	3	2.64	30.6 bu
15	Wheat	4949	Gravelly Clay............	3.16	2.36	6-10	50	4	3.10	35.8 bu
16	Wheat	4949	Gravelly Clay............	3.07	2.36	6-9	50	5	3.96	39.0 bu
17	Oats	4699	Very Gravelly...........	2.44	2.36	6-3	71	4	4.48	21.7 bu
18	Oats	4699	Very Gravelly...........	3.78	2.36	6-4	62	4	4.14	34.2 bu
19	Oats	4699	Very Gravelly...........	4.50	2.36	6-2	79	6	5.68	33.2 bu
20	Oats	4742	Impervious Clay Loam..	3.46	2.36	6-23	51	3	.99	44.5 bu
21	Oats	4742	Impervious Clay Loam..	3.44	2.36	6-24	52	3	1.22	49.7 bu
22	Oats	4742	Impervious Clay Loam..	3.66	2.36	6-22	51	3	1.71	54.3 bu
23	Wheat	4497	Very Sandy..............	4.11	2.23	7-2	...	1	.76	27.8 bu
24	Wheat	4497	Very Sandy..............	2.72	2.23	6-25	...	1	1.05	26.9 bu
25	Wheat	4497	Very Sandy..............	4.76	2.23	6-9	15	2	2.93	27.3 bu
26	Oats	2482	Impervious Clay Loam..	4.36	2.81	5-24	13	3	1.02	21.8 bu
27	Oats	2482	Impervious Clay Loam..	3.56	2.81	5-23	14	3	1.22	33.8 bu
28	Oats	2482	Impervious Clay Loam..	5.09	2.81	5-26	13	3	1.45	29.4 bu
29	Wheat.........	2607	Uniform Clay Loam....	4.24	2.90	5-27	26	2	.72	36.3 bu
30	Wheat.........	2607	Uniform Clay Loam....	3.84	2.90	5-23	30	2	.84	38.0 bu
31	Wheat.........	2607	Uniform Clay Loam....	3.98	2.90	5-27	30	2	1.13	34.4 bu
32	Oats............	2460	Coarse Sandy Loam....	3.61	3.04	5-21	47	3	1.00	58.0 bu
33	Oats..........	2460	Coarse Sandy Loam....	2.77	3.04	5-20	56	5	1.36	55.0 bu
34	Oats............	2460	Coarse Sandy Loam....	2.57	3.04	5-19	61	5	2.31	47.0 bu
35	Wheat.........	3800	Uniform Clay Loam....	4.72	1.85	5-26	35	2	.55	8.3 bu
36	Wheat.........	3800	Uniform Clay Loam....	4.55	1.85	5-26	35	2	.89	15.9 bu
37	Wheat.........	3800	Uniform Clay Loam....	4.43	1.85	5-26	35	2	.95	12.4 bu
38	Oats............	2482	Impervious Clay Loam.	5.16	2.81	6-15	41	4	.65	16.1 bu
39	Oats............	2482	Impervious Clay Loam.	4.03	2.81	6-14	59	5	1.03	25.4 bu
40	Oats............	2482	Impervious Clay Loam.	4.31	2.81	6-18	57	6	1.22	27.3 bu
41	Wheat.........	3572	Medium Clay Loam....	.172	1.85	.....	...	0	.00	436.0 lbs
42	Wheat.........	3572	Medium Clay Loam....	.089	1.85	5-20	25	2	.533	1123.6 lbs
43	Wheat.........	3572	Medium Clay Loam....	.088	1.85	5-20	43	3	.713	1397.7 lbs
44	Wheat.........	3572	Medium Clay Loam....	.091	1.85	5-20	43	4	.842	1824.2 lbs
45	Wheat.........	35[illegible]	Medium Clay Loam....	.084	1.85	5-20	54	5	1.210	2000.0 lbs
50	Wheat.........	3572	Medium Clay Loam....	.092	1.85	5-20	61	6	1.435	2010.0 lbs
51	Wheat.........	2572	Medium Clay Loam....	.083	1.85	5-21	66	9	2.486	2084.3 lbs
52	Wheat.........	3572	Medium Clay Loam....	.195	1.85	.....	...	0	.000	605.1 lbs
53	Wheat.........	3572	Medium Clay Loam....	.088	1.85	5.20	25	2	.352	1227.3 lbs
54	Wheat.........	3572	Medium Clay Loam....	.088	1.85	5-20	43	3	.533	1238.6 lbs

Table Showing Effects of Using Different Amounts of Water on Grains, Alfalfa, Etc., in Idaho, During the Seasons of 1910-11-12-13.—*Continued.*

Number	Kind of crop	Altitude	Class of soil	Area—acres	In. precipitation Apr. to Sep. inc.	Date of first irrigation	Ir. season—days	No. of irrigat'ns	Total depth irrigation water applied—feet	Yield per acre
	Grain—1910 Continued									
55	Wheat.........	3572	Medium Clay Loam....	.086	1.85	5-20	43	4	.945	1430.2 lbs
56	Wheat.........	3572	Medium Clay Loam....	.089	1.85	5-20	54	5	1.100	1932.6 lbs
57	Wheat.........	3572	Medium Clay Loam....	.074	1.85	5-20	61	6	1.601	2067.5 lbs
58	Wheat.........	3572	Medium Clay Loam....	.089	1.85	5-21	66	9	2.355	2101.1 lbs
59	Wheat.........	3572	Medium Clay Loam....	.176	1.85	.....	...	0	.000	522.7 lbs
60	Wheat.........	3572	Medium Clay Loam....	.088	1.85	5-20	25	2	.434	1227.3 lbs
61	Wheat.........	3572	Medium Clay Loam....	.089	1.85	5-20	43	3	.594	1359.7 lbs
62	Wheat.........	3572	Medium Clay Loam.....	.091	1.85	5-20	43	4	.907	1824.2 lbs
63	Wheat.........	3572	Medium Clay Loam....	.088	1.85	5-20	54	5	1.091	2102.3 lbs
64	Wheat.........	3572	Medium Clay Loam....	.093	1.85	5-21	60	7	1.786	2258.0 lbs
65	Wheat.........	3572	Medium Clay Loam....	.074	1.85	5-21	66	9	3.010	2635.1 lbs
66	Barley.........	3572	Medium Clay Loam....	.962	1.85	5-17	32	3	1.032	1509.4 lbs
67	Barley.........	3572	Medium Clay Loam....	.963	1.85	5-17	58	4	1.312	1797.5 lbs
68	Barley	3572	Medium Clay Loam....	.968	1.85	5-18	68	5	1.879	2026.9 lbs
69	Oats............	3572	Medium Clay Loam....	.959	1.85	5-24	23	2	.560	1444.2 lbs
70	Oats............	3572	Medium Clay Loam....	.957	1.85	5-25	41	3	1.097	1849.5 lbs
71	Oats............	3572	Medium Clay Loam....	.962	1.85	5-23	51	4	1.450	2047.8 lbs
72	Wheat.........	3572	Medium Clay Loam....	.563	1.85	5-26	22	2	.780	1179.4 lbs
73	Wheat.........	3572	Medium Clay Loam....	.591	1.85	5-26	40	3	1.269	1539.8 lbs
74	Wheat.........	3572	Medium Clay Loam....	.769	1.85	5-26	60	4	1.841	1581.3 lbs
75	Wheat.........	3572	Medium Clay Loam....	.959	1.85	5-9	23	2	.808	1379.4 lbs
76	Wheat.........	3572	Medium Clay Loam....	.964	1.85	5-9	42	3	1.101	1211.6 lbs
77	Wheat.........	3572	Medium Clay Loam....	.968	1.85	5-9	51	4	1.327	1742.8 lbs
78	Potatoes.......	3572	Medium Clay Loam....	.641	1.85	5-13	63	3	.876	6302.6 lbs
79	Potatoes.......	3572	Medium Clay Loam....	.652	1.85	5-13	88	5	1.496	11932.5 lbs
80	Potatoes.......	3572	Medium Clay Loam....	.636	1.85	5-13	97	6	2.046	12932.3 lbs
81	Oats............	3572	Medium Clay Loam....	5.70	1.85	5-12	64	3	1.401	43.3 bu
82	Oats............	3572	Medium Clay Loam....	4.48	1.85	5-17	60	4	1.766	54.6 bu
83	Oats............	3572	Medium Clay Loam....	1.98	1.85	5-19	59	4	2.486	73.7 bu
	Alfalfa, Etc. 1910									
1	Alfalfa.........	3572	Medium Clay Loam.....	.983	1.85	5-8	88	6	4.49	8.7 tons
2	Alfalfa	3572	Medium Clay Loam.....	5.75	1.85	5-7	43	2	1.306	3.30 tons
3	Alfalfa.........	3572	Medium Clay Loam.....	3.72	1.85	5-9	79	3	1.872	3.56 tons
4	Alfalfa.........	3572	Medium Clay Loam.....	3.56	1.85	5-10	78	3	2.104	4.74 tons
5	Alfalfa.........	4949	Very Gravelly...........	10.65	2.36	5-27	88	9	11.20	4.2 tons
6	Red Clover...	4949	Very Gravelly...........	3.31	2.36	5-6	113	7	6.92	3.78 tons
7	Red Clover....	4949	Very Gravelly...........	4.32	2.36	5-7	117	9	8.40	4.85 tons
8	Red Clover....	4949	Very Gravelly...........	3.98	2.36	5-4	114	10	12.98	4.60 tons
9	Alfalfa.........	4949	Very Gravelly...........	2.33	2.36	5-3	101	4	6.352	3.78 tons
10	Alfalfa.........	4949	Very Gravelly...........	6.77	2.36	5-2	105	6	6.925	3.65 tons
11	Alfalfa.........	4949	Very Gravelly...........	2.51	2.36	4-27	110	7	9.401	5.20 tons
12	Alfalfa.........	4742	Uniform Clay Loam....	3.20	2.36	5-6	104	4	1.409	5.04 tons
13	Alfalfa.........	4742	Uniform Clay Loam....	3.16	2.36	5-6	102	6	1.953	3.41 tons
14	Alfalfa.........	4742	Uniform Clay Loam....	3.37	2.36	5-6	103	6	2.221	5.72 tons
15	Alfalfa.........	4497	Very Sandy..............	3.38	2.23	5-27	36	3	1.609	4.44 tons
16	Alfalfa.........	4497	Very Sandy..............	4.15	2.23	5-27	50	5	2.649	4.28 tons
17	Alfalfa.........	4497	Very Sandy..............	4.29	2.23	5-27	59	7	4.825	4.57 tons
18	Alfalfa.........	2367	Impervious Clay Loam.	2.81	2.81	3-29	144	8	1.895	4.00 tons

Table Showing Effects of Using Different Amounts of Water on Grains, Alfalfa, Etc., in Idaho, During the Seasons of 1910-11-12-13.—*Continued.*

Number	Kind of crop	Altitude	Class of soil	Area—acres	In. precipitation Apr. to Sep. inc.	Date of first irrigation	Ir season—days	No. of irrigat'ns	Total depth irrigation water applied—feet	Yield per acre
	Alfalfa, Etc. 1910—Cont.									
19	Alfalfa.........	2367	Impervious Clay Loam.	3.69	2.81	3-27	143	8	2.848	3.66 tons
20	Alfalfa.........	2367	Impervious Clay Loam.	2.84	2.81	3-28	144	9	3.457	4.37 tons
21	Alfalfa.........	2482	Impervious Clay Loam	6.32	3.00	5-7	115	7	1.434	2.85 tons
22	Alfalfa.........	2482	Impervious Clay Loam	6.23	3.00	5-5	120	7	2.112	4.93 tons
23	Alfalfa.........	2482	Impervious Clay Loam	6.21	3.00	5-5	99	7	2.251	4.35 tons
24	Alfalfa.........	2607	Uniform Clay Loam....	5.08	2.80	4-28	109	6	2.821	5.15 tons
25	Alfalfa.........	5820	Very Gravelly...........	158.4	3.27	.....	120	..	21.13	3 to 3.5 tons
26	Alfalfa.........	5330	Very Gravelly...........	15.2	3.27	.....	120	..	16.00	3 to 4 tons
27	Alfalfa.........	3572	Clay Loam...............	51.0	1.85	.....	140	..	4.80	4 tons
28	Alfalfa.........	3572	Uniform Clay Loam.....	31.8	1.85	.....	140	..	4.06	4 tons
29	Alfalfa and Wheat.......	3572	Uniform Clay Loam.....	69.6	1.85	.....	140	..	4.00	4 tons
30	Alfalfa.........	3800	Medium Clay Loam.....	2.92	3.04	5-4	105	4	2.34	6.86 tons
31	Alfalfa.........	3800	Medium Clay Loam.....	2.89	3.04	5-5	107	4	4.05	7.04 tons
32	Alfalfa.........	3800	Medium Clay Loam.....	3.38	3.04	5-7	109	4	4.72	7.96 tons
	Grain—1911									
1	Oats...........	3968	Uniform Sandy Loam...	3.56	6.18	7-12	...	1	.453	29.5 bu
2	Oats...........	3968	Uniform Sandy Loam ..	3.66	6.18	6-21	26	2	1.144	45.9 bu
3	Oats...........	3968	Uniform Sandy Loam ..	4.15	6.18	6-17	42	3	1.889	50.8 bu
4	Wheat........	3800	Shallow Clay Loam.....	4.24	5.35	6-11	15	2	.864	30.6 bu
5	Wheat........	3800	Shallow Clay Loam.....	4.73	5.35	6-7	43	3	1.623	33.8 bu
6	Wheat........	3800	Shallow Clay Loam.....	3.25	5.35	6-5	51	4	2.153	38.0 bu
7	Wheat........	3750	Medium Clay Loam.....	3.59	5.50	6-24	19	2	.635	63.2 bu
8	Wheat........	3750	Medium Clay Loam.....	7.49	5.50	6-17	32	2	1.123	53.4 bu
9	Wheat........	3750	Medium Clay Loam.....	5.42	5.50	6-14	27	2	1.808	64.0 bu
10	Oats...........	3750	Medium Clay Loam.....	5.80	5.50	6-2	52	3	1.161	64.3 bu
11	Oats..........	3750	Medium Clay Loam.....	4.82	5.50	6-1	47	3	1.414	51.9 bu
12	Oats...........	3750	Medium Clay Loam.....	7.02	5.50	5-29	64	4	1.442	65.3 bu
13	Oats...........	3825	Medium Clay Loam......	4.01	3.19	6-28	...	1	.302	56.6 bu
14	Oats...........	3825	Medium Clay Loam......	6.10	3.19	6-20	35	2	1.167	63.2 bu
15	Oats...........	3825	Medium Clay Loam......	4.03	3.19	6-8	53	3	2.266	68.9 bu
16	Orchard......	3825	Medium Clay Loam.....	4.580	3.19	7-6	...	1	.268	*
17	Fall Rye.....	3700	Very Sandy Loam.......	6.89	5.30	5-12	...	1	.729	11.6 bu
18	Oats...........	3700	Very Sandy Loam.......	4.29	5.30	6-8	45	3	.656	23.3 bu
19	Oats...........	3700	Very Sandy Loam.......	4.01	5.30	6-6	43	3	.888	26.0 bu
20	Oats...........	3700	Very Sandy Loam.......	4.17	5.30	6-1	54	4	1.047	35.0 bu
21	Potatoes......	3700	Extremely Sandy.........	2.89	5.30	7-12	40	3	.613	112.8 bu
22	Potatoes......	3700	Extremely Sandy.........	2.90	5.30	6-19	46	3	.955	108.1 bu
23	Potatoes......	3700	Extremely Sandy.........	3.27	5.30	6-22	59	4	1.062	128.1 bu
24	Oats...........	4100	Deep Clay Loam..........	4.98	5.80	6-25	...	1	.641	76.5 bu
25	Oats...........	4100	Deep Clay Loam..........	5.11	5.80	6-22	...	1	1.316	73.5 bu
26	Oats...........	4100	Deep Clay Loam..........	4.42	5.80	6-15	...	1	1.654	72.4 bu
27	Wheat........	4949	Very Gravelly............	15.51	6.95	7-3	49	3	1.377	20.9 bu
28	Wheat........	4949	Shallow Sandy Loam....	14.91	6.95	6-16	53	3	5.342	30.0 bu

*4 years old. No crop.

Table Showing Effects of Using Different Amounts of Water on Grains, Alfalfa, Etc., in Idaho, During the Seasons of 1910-11-12-13.—*Continued.*

Number	Kind of crop	Altitude	Class of soil	Area—acree	In. precipitation Apr. to Sep. inc.	Date of first irrigation	Ir. season—days	No. of irrigat'ns	Total depth irrigation water applied—feet	Yield per acre
	Grain—1911 Continued									
29	Potatoes......	4949	Sandy Loam..............	7.11	6.95	7-20	46	4	2.828	211.8 bu
30	Wheat........	4949	Shallow Sandy Loam...	9.83	6.95	6-20	42	3	3.466	31.6 bu
31	Oats...........	4949	Sandy Loam..............	3.85	6.95	7-16	36	3	4.511	31.8 bu
32	Oats...........	4949	Sandy Loam..............	2.55	6.95	6-30	54	4	5.943	68.4 bu
33	Oats...........	4949	Sandy Loam..............	2.96	6.95	6-28	53	5	10.366	57.2 bu
34	Wheat........	2600	Impervious Clay Loam..	8.47	4.09	6-1	39	2	.307	19.7 bu
35	Wheat........	2600	Impervious Clay Loam..	11.05	4.09	6-7	...	1	.315	16.0 bu
36	Wheat........	2600	Impervious Clay Loam..	8.64	4.09	6-5	38	3	.589	22.0 bu
37	Wheat........	2600	Impervious Clay Loam..	2.05	4.09	6-25	19	3	.263	12.0 bu
38	Wheat........	2600	Impervious Clay Loam..	1.19	4.09	6-26	15	2	.271	5.0 bu
39	Wheat........	2600	Impervious Clay Loam..	1.65	4.09	6-25	22	3	.497	5.0 bu
40	Oats...........	2600	Impervious Clay Loam..	3.06	4.09	6-24	18	2	.294	22.0 bu
41	Oats...........	2600	Impervious Clay Loam..	2.08	4.09	6-23	21	3	.372	26.0 bu
42	Oats...........	2600	Impervious Clay Loam..	2.60	4.09	6-24	23	3	.417	26.0 bu
43	Oats...........	2600	Sandy Loam..............	5.38	4.09	5-30	...	1	.185	16.0 bu
44	Oats...........	2600	Sandy Loam..............	7.29	4.09	5-24	...	1	.199	10.6 bu
45	Oats...........	2600	Sandy Loam..............	6.25	4.09	6-3	...	1	.248	17.7 bu
46	Oats...........	2607	Impervious Clay Loam.	4.56	6.80	6-12	25	2	.557	28.0 bu
47	Oats...........	2607	Impervious Clay Loam.	1.35	6.80	6-12	25	2	.618	34.8 bu
48	Oats...........	2607	Impervious Clay Loam..	3.69	6.80	6-13	24	2	.769	31.4 bu
49	Oats...........	2460	Clay Loam...............	2.58	6.80	6-2	28	2	.461	43.0 bu
50	Oats...........	2460	Clay Loam...............	2.30	6.80	6-4	38	3	.698	63.0 bu
51	Oats...........	2460	Clay Loam...............	2.37	6.80	6-3	39	3	1.076	73.0 bu
52	Wheat........	2607	Sandy Loam.............	2.56	6.80	6-8	23	2	1.193	49.0 bu
53	Wheat........	2607	Sandy Loam.............	6.17	6.80	6-8	38	3	1.371	35.5 bu
54	Wheat........	2607	Sandy Loam.............	5.79	6.80	6-8	23	2	1.428	37.6 bu
55	Wheat........	2460	Sandy Loam Mixed	4.40	6.80	6-27	19	2	.770	45.4 bu
56	Wheat........	2460	With Clay.............	5.55	6.80	6-25	19	2	1.367	49.5 bu
57	Oats...........	2547	Sandy Loam.............	6.72	6.80	6-12	35	3	1.258	47.3 bu
58	Oats...........	2547	Sandy Loam.............	4.16	6.80	6-7	32	2	1.315	59.3 bu
59	Oats...........	2547	Sandy Loam.............	5.67	6.80	6-5	32	3	3.095	54.1 bu
60	Wheat........	2400	Coarse Sandy Loam.....	3.74	6.80	6-9	33	2	.866	27.8 bu
61	Wheat........	2400	Coarse Sandy Loam.....	6.21	6.80	6-9	34	3	1.186	43.96 bu
62	Wheat........	2400	Coarse Sandy Loam.....	4.14	6.80	6-10	34	3	1.253	33.59 bu
63	Oats...........	5330	Very Gravelly............	4.03	6.18	7-15	18	2	3.187	45.6 bu
64	Oats...........	5330	Very Gravelly............	8.63	6.18	7-12	20	2	4.280	39.9 bu
65	Oats...........	5330	Very Gravelly............	5.55	6.18	6-23	38	3	6.304	40.9 bu
66	Orchard.......	2460	Clay Loam...............	35.00	6.80	.....	122	..	4.25	*
67	Orchard.......	2547	Coarse Sandy Loam.....	13.15	6.80	.....	122	..	5.26	*
68	Orchard.......	2641	Clay Loam...............	31.85	6.80	.....	122	..	3.56	*
69	Orchard.......	2641	Clay Loam...............	39.72	6.80	.....	122	..	2.32	*
70	Grain & Alfalfa.........	5330	Very Gravelly............	35.59	6.18	6-13	71	..	9.484	3.0 T. Alf. & 30 Bu Oats
71	Oats..........:	2600	Impervious Clay Loam.	2.02	4.09	5-11	64	4	.525	11.0 bu

*Yield not measured.

Table Showing Effects of Using Different Amounts of Water on Grains, Alfalfa, Etc., in Idaho, During the Seasons of 1910-11-12-13.—*Continued.*

Number	Kind of crop	Altitude	Class of soil	Area—acres	In. precipitation Apr. to Sep. inc.	Date of first irrigation	Ir. season—days	No. of irrigat'ns	Total depth irrigation water applied—feet	Yield per acre
	Grain 1911 Continued									
72	Oats..........	2600	Impervious Clay Loam.	2.03	4.09	5-13	59	5	.825	31.0 bu
73	Oats..........	2600	Impervious Clay Loam.	2.03	4.09	5-12	61	5	.967	33.5 bu
74	Corn..........	3700	Extremely Sandy........	3.91	5.30	6-20	54	3	.789	4.00 tons
75	Corn..........	3700	Extremely Sandy........	4.34	5.30	6-22	57	3	.789	4.00 tons
76	Corn..........	3700	Extremely Sandy........	4.66	5.30	6-20	57	3	1.381	4.00 tons
77	Wheat........	3572	Medium Clay Loam.....	.189	3.98	.....	...	0	.000	952.37 lbs
78	Wheat........	3572	Medium Clay Loam.....	.092	3.98	6-1	...	1	.479	1108.69 lbs
79	Wheat........	3572	Medium Clay Loam.....	.096	3.98	6-2	41	3	1.285	1322.91 lbs
80	Wheat........	3572	Medium Clay Loam.....	.097	3.98	6-2	42	5	1.516	1371.13 lbs
81	Wheat........	3572	Medium Clay Loam.....	.092	3.98	6-2	48	4	1.737	1565.21 lbs
82	Wheat........	3572	Medium Clay Loam.....	.091	3.98	6-2	55	7	2.558	1472.53 lbs
83	Wheat........	3572	Medium Clay Loam.....	.092	3.98	6-3	54	10	2.820	1021.73 lbs
84	Wheat........	3572	Medium Clay Loam......	.189	3.98	.....	...	0	.000	973.54 lbs
85	Wheat........	3572	Medium Clay Loam......	.094	3.98	6-1	...	1	.379	1095.74 lbs
86	Wheat........	3572	Medium Clay Loam......	.093	3.98	6-2	42	3	1.184	1193.54 lbs
87	Wheat........	3572	Medium Clay Loam......	.095	3.98	6-2	48	4	1.374	1389.47 lbs
88	Wheat........	3572	Medium Clay Loam......	.092	3.98	6-2	42	5	1.861	1130.43 lbs
89	Wheat........	3572	Medium Clay Loam......	.094	3.98	6-2	55	7	2.853	1351.06 lbs
90	Wheat........	3572	Medium Clay Loam......	.094	3.98	6-3	54	10	3.156	797.87 lbs
91	Wheat........	3572	Medium Clay Loam......	.189	3.98	.....	...	0	.000	1063.49 lbs
92	Wheat........	3572	Medium Clay Loam......	.091	3.98	6-1	...	1	.417	1285.71 lbs
93	Wheat........	3572	Medium Clay Loam......	.093	3.98	6-2	42	3	1.148	1709.67 lbs
94	Wheat........	3572	Medium Clay Loam......	.090	3.98	6-2	48	4	1.451	1833.33 lbs
95	Wheat........	3572	Medium Clay Loam......	.094	3.98	6-2	42	5	1.842	1563.83 lbs
96	Wheat........	3572	Medium Clay Loam......	.093	3.98	6-3	54	7	2.161	1139.78 lbs
97	Wheat........	3572	Medium Clay Loam......	.096	3.98	6-3	54	10	2.834	968.75 lbs
98	Oats..........	3572	Medium Clay Loam......	.63	3.98	6-16	...	1	.376	1333.33 lbs
99	Oats..........	3572	Medium Clay Loam......	.63	3.98	6-10	30	3	.962	1501.58 lbs
100	Oats..........	3572	Medium Clay Loam......	.61	3.98	6-6	42	5	1.533	1670.49 lbs
101	Wheat........	3572	Medium Clay Loam......	.990	3.98	6-9	...	1	.460	1719.19 lbs
102	Wheat........	3572	Medium Clay Loam......	.982	3.98	6-5	17	2	1.009	1450.10 lbs
103	Wheat........	3572	Medium Clay Loam......	.982	3.98	6-3	34	4	1.402	1446.02 lbs
104	Barley........	3572	Medium Clay Loam......	.985	3.89	6-21	...	1	.555	1470.05 lbs
105	Barley........	3572	Medium Clay Loam......	.965	3.98	6-18	20	2	.953	1842.48 lbs
106	Barley........	3572	Medium Clay Loam......	.951	3.98	6-17	30	3	1.678	1590.95 lbs
107	Wheat........	3572	Medium Clay Loam......	.610	3.98	6-15	...	1	.419	1754.09 lbs
108	Wheat........	3572	Medium Clay Loam......	.622	3.98	6-13	34	3	.909	1860.12 lbs
109	Wheat........	3572	Medium Clay Loam......	.641	3.98	6-14	40	5	1.788	1893.91 lbs
110	Potatoes......	3572	Medium Clay Loam......	.630	3.98	7-9	...	1	.539	7349.2 lbs
111	Potatoes......	3572	Medium Clay Loam......	.630	3.98	7-2	40	5	2.208	16738.0 lbs
112	Potatoes......	3572	Medium Clay Loam......	.610	3.98	6-29	41	5	3.644	16754.0 lbs
	Alfalfa, Etc. 1911									
1	Alfalfa........	3572	Medium Clay Loam.....	.943	3.98	5-10	105	3	1.775	7534.0 lbs
2	Alfalfa........	3572	Medium Clay Loam.....	.930	3.98	5-10	128	6	3.329	10608.0 lbs
3	Alfalfa........	3572	Medium Clay Loam.....	.965	3.98	5-11	128	8	4.000	13233.0 lbs
4	Alfalfa........	3800	Shallow Clay Loam.....	4.69	5.35	5-9	109	4	1.962	5.83 tons
5	Alfalfa........	3800	Shallow Clay Loam.....	5.38	5.35	5-12	116	6	2.327	5.57 tons
6	Alfalfa........	3800	Shallow Clay Loam.....	3.85	5.35	5-8	108	5	2.549	5.25 tons
7	Alfalfa........	3750	Medium Clay Loam.....	3.72	5.35	5-31	86	4	2.677	4.56 tons
8	Alfalfa........	3750	Medium Clay Loam.....	2.67	5.35	5-21	95	5	3.263	6.00 tons
9	Alfalfa........	3750	Medium Clay Loam.....	3.76	5.35	5-19	119	6	3.786	6.00 tons

Table Showing Effects of Using Different Amounts of Water on Grains, Alfalfa, Etc., in Idaho, During the Seasons of 1910-11-12-13.—*Continued.*

Number	Kind of crop	Altitude	Class of soil	Area —acres	In. precipitation Apr. to Sep. inc.	Date of first irrigation	Ir. season—days	No. of irrigat'ns	Total depth irrigation water applied—feet	Yield per acre
	Alfalfa, Etc. 1911—Cont.									
10	Alfalfa........	3800	Medium Clay Loam.....	4.17	3.19	5-4	80	2	1.286	6.1 tons
11	Alfalfa........	3800	Medium Clay Loam.....	4.22	3.19	5-6	135	4	3.194	6.4 tons
12	Alfalfa........	3800	Medium Clay Loam.....	4.96	3.19	5-8	135	5	3.981	5.76 tons
13	Alfalfa........	3825	Medium Clay Loam.....	4.37	3.19	5-17	105	3	1.309	4.73 tons
14	Alfalfa........	3825	Medium Clay Loam.....	4.19	3.19	5-13	112	4	2.767	5.44 tons
15	Alfalfa........	3825	Medium Clay Loam.....	4.78	3.19	5-14	106	5	3.211	4.97 tons
16	Alfalfa........	3700	Very Sandy Loam.......	2.65	5.30	5-10	119	6	1.894	1.50 tons
17	Alfalfa........	3700	Very Sandy Loam.......	1.80	5.30	5-4	125	6	2.611	2.74 tons
18	Alfalfa........	4100	Deep Clay Loam.........	9.98	5.80	5-20	...	1	.993	3.1 tons
19	Alfalfa........	4949	Very Gravelly...........	10.65	6.95	5-19	108	8	11.532	4.54 tons
20	Alfalfa........	4949	Very Gravelly...........	5.45	6.95	5-22	77	4	5.402	1.99 tons
21	Alfalfa........	4949	Very Gravelly...........	5.28	6.95	5-23	94	7	6.400	3.42 tons
22	Alfalfa........	4949	Very Gravelly...........	5.73	6.95	5-22	94	6	7.224	3.27 tons
23	Clover.........	4949	Very Gravelly...........	3.31	6.95	5-20	88	5	5.246	2.69 tons
24	Clover.........	4949	Very Gravelly...........	4.32	6.95	5-20	103	7	6.611	3.25 tons
25	Clover.........	4949	Very Gravelly...........	3.98	6.95	5-19	109	9	14.721	2.91 tons
26	Alfalfa........	2607	Clay Loam...............	3.37	6.80	6-3	103	7	1.535	0.1 tons
27	Alfalfa........	2607	Clay Loam...............	3.48	6.80	6-3	103	8	2.912	0.1 tons
28	Alfalfa........	2607	Clay Loam...............	3.37	6.80	6-3	103	8	4.114	0.89 tons
29	Alfalfa.......	2607	Impervious Clay Loam.	4.94	6.80	4-26	141	9	2.136	2.11 tons
30	Alfalfa........	2607	Impervious Clay Loam.	4.21	6.80	4-25	142	11	3.511	3.93 tons
31	Alfalfa........	2607	Impervious Clay Loam.	9.39	6.80	4-25	141	12	3.814	4.39 tons
32	Timothy & Clover.......	2547	Dark Sandy Loam......	5.43	6.80	4-21	122	7	3.257	4.63 tons
33	Timothy & Clover.......	2547	Dark Sandy Loam......	5.46	6.80	4-26	119	8	4.437	4.57 tons
34	Timothy & Clover.......	2547	Dark Sandy Loam......	4.53	6.80	4-25	119	9	6.040	3.84 tons
35	Alfalfa and Grain........	5820	Very Gravelly...........	156.3	6.18	6-11	67	..	10.91	3.00 tons
36	Alfalfa........	5330	Very Gravelly...........	40.49	6.18	6-15	65	..	8.562	3.00 tons
	Grain—1912									
1	Wheat........	3800	Medium Clay Loam....	2.37	3.71	6-21	...	1	.735	67.5 bu
2	Wheat........	3800	Medium Clay Loam....	6.54	3.71	6-24	...	1	.871	72.1 bu
3	Wheat........	3800	Medium Clay Loam....	8.27	3.71	6-18	36	2	1.158	82.9 bu
4	Orchard......	3825	Medium Clay Loam.....	4.58	3.71	8-1	...	1	.143	*
5	Wheat........	4000	Shallow Gravelly Clay..	5.68	3.71	6-7	22	2	.927	31.16 bu
6	Wheat........	4000	Shallow Gravelly Clay..	7.72	3.71	6-9	35	3	1.436	37.65 bu
7	Wheat........	4000	Shallow Gravelly Clay..	4.16	3.71	6-6	51	4	1.598	28.60 bu
8	Oats..........	4000	Shallow Clay Loam....	1.83	3.71	6-5	39	2	.487	10.92 bu
9	Oats..........	4000	Shallow Clay Loam....	3.86	3.71	6-3	53	3	1.427	25.90 bu
10	Oats..........	4000	Shallow Clay Loam....	3.23	3.71	6-1	57	4	1.748	24.76 bu
11	Wheat........	3800	Shallow Clay Loam....	6.91	3.81	6-26	...	1	.276	15.92 bu
12	Wheat........	3800	Shallow Clay Loam....	6.05	3.81	6-18	37	2	.791	18.02 bu
13	Wheat........	3800	Shallow Clay Loam....	6.09	3.81	6-23	34	3	1.214	24.11 bu
14	Wheat........	3750	Deep Clay Loam.........	4.85	3.81	6-3	39	2	.967	39.59 bu
15	Wheat........	3750	Deep Clay Loam.........	4.41	3.81	6-4	60	3	1.655	43.76 bu

* Only five years old, very small yield, not measured.

Table Showing Effects of Using Different Amounts of Water on Grains, Alfalfa, Etc., in Idaho, During the Seasons of 1910-11-12-13.—*Continued.*

Number	Kind of crop	Altitude	Class of soil	Area —acres	In. precipitation Apr. to Sep inc.	Date of first irrigation	Ir. season—days	No. of irrigat'ns	Total depth irrigation water applied—feet	Yield per acre
	Grain—1912 Continued									
16	Wheat........	3750	Deep Clay Loam.........	4.78	3.81	6-2	61	3	2.053	42.05 bu
17	Orchard......	3800	Shallow Clay Loam.....	8.40	3.81	7-12	...	1	.093	*
18	Wheat........	2763	Impervious Clay Loam.	.153	8.25	.....	...	0	.000	784.3 lbs
19	Wheat........	2763	Impervious Clay Loam.	.170	8.25	6-25	...	1	.344	1058.81 lbs
20	Wheat........	2763	Impervious Clay Loam.	.184	8.25	6-25	9	2	.529	1304.32 lbs
21	Wheat........	2763	Impervious Clay Loam.	.173	8.25	6-12	22	3	.690	1734.09 lbs
22	Wheat........	2763	Impervious Clay Loam.	.161	8.25	6-12	36	4	.950	1863.33 lbs
23	Wheat........	2763	Impervious Clay Loam.	.178	8.25	6-12	36	4	.862	2022.48 lbs
24	Wheat........	2763	Impervious Clay Loam.	.165	8.25	6-12	43	5	1.042	3272.72 lbs
25	Wheat........	2607	Impervious Clay Loam.	3.98	8.25	6-5	39	2	.780	34.92 bu
26	Wheat........	2607	Impervious Clay Loam.	1.42	8.25	6-7	51	3	.951	37.32 bu
27	Wheat........	2607	Impervious Clay Loam.	3.57	8.25	6-3	54	4	1.186	38.38 bu
28	Wheat........	2607	Clay Loam...............	13.36	8.25	6-19	30	2	2.473	31.81 bu
29	Oats...........	4949	Very Gravelly...........	5.40	8.51	6-28	40	3	2.953	76.7 bu
30	Oats...........	4949	Very Gravelly...........	5.52	8.51	6-29	48	3	3.236	63.0 bu
31	Oats...........	4949	Very Gravelly...........	5.73	8.51	6-28	49	3	4.263	74.7 bu
32	Wheat........	3572	Medium Clay Loam.....	.689	3.47	5-29	...	1	.638	2367.3 lbs
33	Wheat........	3572	Medium Clay Loam.....	.636	3.47	5-28	23	2	1.087	2336.1 lbs
34	Wheat........	3572	Medium Clay Loam.....	.625	3.47	5-27	30	4	1.653	2326.7 lbs
35	Wheat........	3572	Medium Clay Loam.....	.186	3.47	.....	...	0	.000	1087.7 lbs
36	Wheat........	3572	Medium Clay Loam.....	.097	3.47	6-3	...	1	.589	1104.2 lbs
37	Wheat........	3572	Medium Clay Loam.....	.088	3.47	6-3	30	3	1.244	1530.6 lbs
38	Wheat........	3572	Medium Clay Loam.....	.094	3.47	6-4	28	4	1.475	1525.4 lbs
39	Wheat........	3572	Medium Clay Loam.....	.091	3.47	6-4	44	6	1.806	1444.3 lbs
40	Wheat........	3572	Medium Clay Loam.....	.093	3.47	6-4	44	7	2.381	1652.3 lbs
41	Wheat........	3572	Medium Clay Loam.....	.089	3.47	6-4	52	10	2.638	2022.3 lbs
42	Wheat........	3572	Medium Clay Loam.....	.186	3.47	.....	...	0	.000	912.7 lbs
43	Wheat........	3572	Medium Clay Loam.....	.091	3.47	6-3	...	1	.343	1207.2 lbs
44	Wheat........	3572	Medium Clay Loam.....	.092	3.47	6-3	29	3	1.190	1207.8 lbs
45	Wheat........	3572	Medium Clay Loam.....	.088	3.47	6-4	28	4	1.179	1775.6 lbs
46	Wheat........	3572	Medium Clay Loam.....	.094	3.47	6-4	44	6	2.125	1483.0 lbs
47	Wheat........	3572	Medium Clay Loam.....	.090	3.47	6-4	44	7	2.216	1770.9 lbs
48	Wheat........	3572	Medium Clay Loam.....	.097	3.47	6-4	52	10	2.798	1780.2 lbs
49	Wheat........	3572	Medium Clay Loam.....	.183	3.47	.....	...	0	.000	1042.5 lbs
50	Wheat........	3572	Medium Clay Loam.....	.094	3.47	6-3	...	1	.481	1122.8 lbs
51	Wheat........	3572	Medium Clay Loam.....	.090	3.47	6-3	29	3	1.273	1407.8 lbs
52	Wheat........	3572	Medium Clay Loam.....	.092	3.47	6-4	29	4	1.272	1469.0 lbs
53	Wheat........	3572	Medium Clay Loam.....	.086	3.47	6-4	44	6	1.815	1586.9 lbs
54	Wheat........	3572	Medium Clay Loam.....	.094	3.47	6-4	45	7	2.146	1536.0 lbs
55	Wheat........	3572	Medium Clay Loam.....	.084	3.47	6-4	52	10	2.436	1846.0 lbs
56	Oats...........	3572	Medium Clay Loam.....	.383	3.47	6-6	...	1	.418	2362.3 lbs
57	Oats...........	3572	Medium Clay Loam.....	.378	3.47	6-6	36	3	.857	2992.3 lbs
58	Oats...........	3572	Medium Clay Loam.....	.383	3.47	6-4	43	5	1.267	3333.3 lbs
59	Oats...........	3572	Medium Clay Loam.....	.390	3.47	6-5	49	7	1.577	3264.9 lbs
60	Oats...........	3572	Medium Clay Loam.....	.334	3.47	6-4	50	9	2.036	3830.5 lbs
61	Barley........	3572	Medium Clay Loam.....	.325	3.47	6-11	...	1	.434	2505.3 lbs
62	Barley........	3572	Medium Clay Loam.....	.326	3.47	6-11	29	3	1.061	4074.1 lbs
63	Barley........	3572	Medium Clay Loam.....	.312	3.47	6-12	37	5	1.521	4320.5 lbs
64	Potatoes......	3572	Medium Clay Loam.....	.627	3.47	7-1	17	2	.541	12135.0 lbs
65	Potatoes......	3572	Medium Clay Loam.....	.628	3.47	6-30	44	5	1.943	18613.0 lbs
66	Potatoes......	3572	Medium Clay Loam.....	.636	3.47	6-29	53	7	2.516	16681.0 lbs

* Only five years old, very small yield, not measured.

Table Showing Effects of Using Different Amounts of Water on Grain,s Alfalfa, Etc., in Idaho, During the Seasons of 1910-11-12-13.—*Continued.*

Number	Kind of crop	Altitude	Class of soil	Area —acres	In. precipitation Apr. to Sep. inc.	Date of first irrigation	Ir. season—days	No. of irrigat'ns	Total depth irrigation water applied—feet	Yield per acre
	Alfalfa, Etc. —1912									
1	Alfalfa........	3572	Medium Clay Loam.....	.372	3.47	5-27	44	2	.615	5695.0 lbs
2	Alfalfa........	3572	Medium Clay Loam.....	.585	3.47	5-14	65	4	1.308	8003.0 lbs
3	Alfalfa........	3572	Medium Clay Loam.....	.372	3.47	5-14	78	7	2.059	10828.0 lbs
4	Alfalfa........	3572	Medium Clay Loam.....	.569	3.47	5-14	84	9	2.533	11317.0 lbs
5	Alfalfa........	3572	Medium Clay Loam.....	.369	3.47	5-14	88	11	2.931	12506.0 lbs
6	Alfalfa........	3572	Medium Clay Loam.....	.580	3.47	5-15	86	13	4.003	12612.0 lbs
7	Alfalfa........	3800	Medium Clay Loam......	6.02	3.71	5-22	95	3	1.708	5.94 tons
8	Alfalfa........	3800	Medium Clay Loam......	7.49	3.71	5-24	90	3	2.070	5.84 tons
9	Alfalfa........	3800	Medium Clay Loam......	7.71	3.71	5-16	123	6	3.381	5.70 tons
10	Alfalfa........	3800	Shallow Clay Loam......	4.24	3.81	5-14	107	7	2.339	6.44 tons
11	Alfalfa........	3800	Shallow Clay Loam......	3.38	3.81	5-14	107	6	2.513	5.90 tons
12	Alfalfa........	3800	Shallow Clay Loam......	3.75	3.81	5-13	107	9	3.153	7.04 tons
13	Alfalfa........	3750	Deep Clay Loam.........	4.74	3.81	5-31	97	3	1.064	4.67 tons
14	Alfalfa........	3750	Deep Clay Loam.........	4.82	3.81	5-24	92	4	1.589	4.42 tons
15	Alfalfa........	3750	Deep Clay Loam.........	5.28	3.81	5-24	100	4	1.799	4.80 tons
16	Alfalfa........	3800	Shallow Clay Loam.....	14.28	3.81	5-27	98	4	2.413	6.00 tons
17	Alfalfa........	2607	Clay Loam................	4.77	8.25	5-17	101	6	1.870	4.31 tons
18	Alfalfa........	2607	Clay Loam................	3.62	8.25	5-16	98	6	2.961	4.11 tons
19	Alfalfa........	2607	Clay Loam................	6.10	8.25	5-19	105	7	2.887	3.89 tons
20	Alfalfa........	4949	Porous Gravelly..........	4.36	8.51	5-31	75	5	1.983	2.52 tons
21	Alfalfa........	4949	Porous Gravelly..........	4.94	8.51	6-21	55	3	2.027	1.48 tons
22	Alfalfa........	4949	Porous Gravelly..........	4.75	8.51	6-1	75	6	2.582	1.58 tons
23	Alfalfa........	4949	Porous Gravelly..........	3.68	8.51	6-4	71	4	3.047	1.82 tons
24	Alfalfa........	4949	Porous Gravelly..........	2.65	8.51	6-5	71	4	3.307	2.00 tons
25	Alfalfa........	4949	Porous Gravelly..........	2.13	8.51	6-4	71	4	6.721	2.50 tons
	Grains, Etc. —1913									
1	Alfalfa	4550	Clay Loam................	2.70	7.35	5-31	90	3	1.2850	3.06 tons
2	Alfalfa........	4550	Clay Loam................	3.45	7.35	5-31	87	4	1.9607	2.51 tons
3	Alfalfa........	4550	Clay Loam................	3.44	7.35	5-30	89	6	2.6876	3.03 tons
4	Big "4" Oats	4550	Clay Loam................	5.08	7.35	7-2	...	1	.3554	33.85 bu
5	Big "4" Oats	4550	Clay Loam................	5.06	7.35	6-30	29	2	.8939	36.95 bu
6	Big "4" Oats	4550	Clay Loam................	5.07	7.35	6-28	29	2	1.3291	33.82 bu
7	Wheat.........	4550	Clay Loam................	3.01	7.35	6-22	23	2	.9954	24.24 bu
8	Wheat.........	4550	Clay Loam................	4.17	7.35	6.24	38	3	1.6230	25.77 bu
9	Wheat.........	4550	Clay Loam................	3.03	7.35	6-6	58	4	2.3346	16.99 bu
10	Wheat........	4550	Clay Loam................	3.53	7.35	5-10	109	5	2.3445	17.13 bu
11	Wheat........	4550	Clay Loam................	6.06	7.35	5-14	99	4	2.6808	18.72 bu
12	Wheat........	4550	Clay Loam................	4.45	7.35	5-10	105	5	3.2882	20.45 bu
13	Alfalfa........	4850	Deep Uniform Clay.....	7.52	7.35	5-29	63	2	1.4190	3.83 tons
14	Alfalfa........	4850	Deep Loam Clay........	5.12	7.35	5-7	107	3	2.4645	4.00 tons
15	Alfalfa........	4850	Deep Loam Clay........	6.60	7.35	5-4	109	4	3.7354	3.68 tons
16	Wheat........	4700	Deep Unif'm Clay L'm...	6.00	7.35	6-30	39	3	.7579	24.66 bu
17	Wheat........	4700	Deep Unif'm Clay L'm...	5.16	7.35	6-27	35	3	1.3089	23.83 bu
18	Wheat........	4700	Deep Unif'm Clay L'm...	3.07	7.35	6-25	43	3	2.2844	31.59 bu
19	Big "4" Oats	4700	Deep Unif'm Clay L'm...	4.73	7.35	6-8	58	3	.7833	41.22 bu
20	Big "4" Oats	4700	Deep Unif'm Clay L'm...	4.80	7.35	6-6	47	3	1.2642	41.45 bu
21	Big "4" Oats	4700	Deep Unif'm Clay L'm...	4.90	7.35	6-5	49	3	1.5722	41.22 bu

Table Showing Effects of Using Different Amounts of Water on Grains, Alfalfa, Etc., in Idaho, During the Seasons of 1910-11-12-13.—*Continued.*

Number	Kind of crop	Altitude	Class of soil	Area —acree	In. precipitation Apr. to Sep. inc.	Date of first irrigation	Ir. season—days	No. of irrigat'ns	Total depth irrigation water applied—feet	Yield per acre
	Grains, Etc. 1913—Cont.									
22	Alfalfa........	4300	Deep Clay Loam........	3.82	7.35	5-26	74	3	1.3327	3.94 tons
23	Alfalfa........	4300	Deep Clay Loam........	3.61	7.35	5-7	95	4	2.3552	6.11 tons
24	Alfalfa........	4300	Deep Clay Loam........	5.77	7.35	5-4	112	6	3.5394	6.10 tons
25	Wheat........	4850	Clay Loam...............	4.96	7.35	6-27	13	2	.4737	12.29 bu
26	Wheat........	4850	Clay Loam...............	4.36	7.35	6-24	17	2	.8890	17.20 bu
27	Wheat........	4850	Clay Loam...............	4.83	7.35	6-21	19	2	.9253	3.72 bu
28	Wheat........	4300	Medium Clay Loam.....	3.92	7.35	6-7	25	2	.6553	33.17 bu
29	Wheat........	4300	Medium Clay Loam.....	4.19	7.35	6-4	40	3	1.3949	35.32 bu
30	Wheat........	4300	Medium Clay Loam.....	4.34	7.35	6-5	69	3	2.1856	32.25 bu
31	Wheat........	4300	Medium Clay Loam.....	3.19	7.35	6-28	17	2	.7080	32.28 bu
32	Wheat........	4300	Medium Clay Loam.....	3.18	7.35	6-27	18	2	1.0016	51.57 bu
33	Wheat........	4300	Medium Clay Loam.....	3.43	7.35	6-26	18	2	1.2413	46.80 bu
34	Oats...........	4300	Medium Clay Loam....	4.11	7.35	5-31	70	3	.6514	34.42 bu
35	Oats...........	4300	Medium Clay Loam....	6.25	7.35	5-11	97	4	1.2835	44.88 bu
36	Oats...........	4300	Medium Clay Loam....	2.27	7.35	5-28	72	4	1.6017	49.33 bu
37	Wheat........	4570	Deep Unif'm Clay Loa	7.05	7.86	6-24	...	1	.4930	39.7 bu
38	Oats...........	4570	Deep Unif'm Clay Loa	2.38	7.86	6-25	...	1	.7139	35.7 bu
39	Sugar Beets.	4570	Uniform Clay Loam....	7.83	7.86	8-8	17	2	1.6432	15.72 tons
40	Oats...........	4570	Deep Uniform Clay.....	4.35	7.86	7-12	37	2	1.2930	33.3 bu
41	Oats...........	4570	Deep Uniform Clay.....	4.57	7.86	7-16	34	2	1.7217	36.5 bu
42	Oats...........	4570	Deep Uniform Clay.....	3.91	7.86	7-18	33	2	2.9109	16.6 bu
43	Alfalfa........	4700	Deep Uniform Clay.....	3.58	7.86	5-26	...	1	1.0440	1.76 tons
44	Alfalfa........	4700	Deep Uniform Clay.....	2.69	7.86	5-27	...	1	1.5148	2.6 tons
45	Alfalfa........	4700	Deep Uniform Clay.....	3.70	7.86	5-28	...	1	1.8778	2.84 tons
46	Alfalfa........	4570	Deep Uniform Clay.....	3.12	7.86	5-20	62	2	1.8571	3.9 tons
47	Alfalfa........	4570	Deep Uniform Clay.....	2.82	7.86	5-18	63	2	1.7079	4.1 tons
48	Alfalfa........	4570	Deep Uniform Clay.....	4.05	7.86	5-22	85	3	1.9375	3.89 tons
49	Orchard.......	3825	Medium Clay Loam....	4.58	7.58	7-17	45	3	.3394	300 boxes
50	Wheat........	3572	Uniform Clay Loam...	.190	2.39	.....	...	0	.00	0.00 lbs
51	Wheat........	3572	Uniform Clay Loam...	.0873	2.39	6-3	...	1	.2989	1030.93 lbs
52	Wheat........	3572	Uniform Clay Loam...	.0956	2.39	6-3	35	2	.5147	1558.58 lbs
53	Wheat........	3572	Uniform Clay Loam...	.0987	2.39	6-4	34	3	.5412	1661.60 lbs
54	Wheat........	3572	Uniform Clay Loam...	.0851	2.39	6-4	48	4	.9776	1703.88 lbs
55	Wheat........	3572	Uniform Clay Loam...	.0838	2.39	6-4	48	5	1.1816	1551.31 lbs
56	Wheat........	3572	Uniform Clay Loam...	.0945	2.39	6-5	53	9	1.8633	2571.43 lbs
57	Wheat........	3572	Uniform Clay Loam...	.1925	2.39	.....	...	0	.00	0.00 lbs
58	Wheat........	3572	Uniform Clay Loam...	.0987	2.39	6-3	...	1	.2644	1109.42 lbs
59	Wheat........	3572	Uniform Clay Loam...	.1033	2.39	6-4	34	2	.4749	1839.30 lbs
60	Wheat........	3572	Uniform Clay Loam...	.0838	2.39	6-4	34	3	.6913	2273.27 lbs
62	Wheat........	3572	Uniform Clay Loam...	.0894	2.39	6-4	48	4	1.1846	1879.19 lbs
63	Wheat........	3572	Uniform Clay Loam...	.0945	2.39	6-4	48	5	1.2551	1888.89 lbs
64	Wheat........	3572	Uniform Clay Loam...	.1024	2.39	6-5	53	9	2.1977	3632.81 lbs
65	Wheat........	3572	Uniform Clay Loam...	.1949	2.39	.....	...	0	.00	0.00 lbs
66	Wheat........	3572	Uniform Clay Loam...	.0851	2.39	6-3	...	1	.2576	1339.60 lbs
67	Wheat........	3572	Uniform Clay Loam...	.0801	2.39	6-4	34	2	.4997	1922.60 lbs
68	Wheat........	3572	Uniform Clay Loam...	.0987	2.39	6-4	34	3	.6903	1377.91 lbs
69	Wheat........	3572	Uniform Clay Loam...	.0999	2.39	6-4	48	4	.9300	1321.32 lbs
70	Wheat........	3572	Uniform Clay Loam...	.0869	2.39	6-4	48	5	1.0969	2531.65 lbs
71	Wheat........	3572	Uniform Clay Loam...	.0765	2.39	6-5	53	9	1.8359	3542.48 lbs

Table Showing Effects of Using Different Amounts of Water on Grains, Alfalfa, Etc., in Idaho, During the Seasons of 1910-11-12-13.—*Continued.*

Number	Kind of crop	Altitude	Class of soil	Area —acres	In. precipitation Apr. to Sep. inc.	Date of first irrigation	Ir. season—days	No. of irrigat'ns	Total depth irrigation water applied—feet	Yield per acre
	Grains, Etc. 1913—Cont.									
72	Barley........	3572	Uniform Clay Loam...	.6541	2.39	5-31	...	1	.3902	2057.79 lbs
73	Barley........	3572	Uniform Clay Loam...	.6938	2.39	5-30	24	2	.8168	1948.69 lbs
74	Barley........	3572	Uniform Clay Loam...	.6019	2.39	5-30	36	3	1.4302	2267.82 lbs
75	Barley........	3572	Uniform Clay Loam...	1.4073	2.39	5-1	49	2	1.3714	1227.17 lbs
76	Barley........	3572	Uniform Clay Loam...	.7466	2.39	4-30	90	3	2.6734	1222.88 lbs
77	Barley........	3572	Uniform Clay Loam...	.7400	2.39	4-29	90	5	2.7490	1572.97 lbs
78	Oats..........	3572	Uniform Clay Loam...	.9526	2.39	5-6	34	2	1.2858	1709.10 lbs
79	Oats..........	3572	Uniform Clay Loam...	.4943	2.39	5.7	80	3	1.6123	1723.65 lbs
80	Oats..........	3572	Uniform Clay Loam...	.4943	2.39	5-8	81	5	2.7353	2120.17 lbs
81	Potatoes......	3572	Uniform Clay Loam...	.644	2.39	7-12	...	1	.793	12251.55 lbs
82	Potatoes......	3572	Uniform Clay Loam...	.644	2.39	7-11	32	3	1.250	18416.15 lbs
83	Potatoes......	3572	Uniform Clay Loam...	.618	2.39	7.10	49	6	3.127	22095.47 lbs
84	Alfalfa........	3572	Uniform Clay Loam...	.4325	2.39	5-22	86	3	1.1763	10601.16 lbs
85	Alfalfa........	3572	Uniform Clay Loam...	.5271	2.39	5-21	87	4	1.8194	9685.07 lbs
86	Alfalfa........	3572	Uniform Clay Loam...	.4731	2.39	5-10	97	5	1.8194	10410.06 lbs
87	Alfalfa........	3572	Uniform Clay Loam...	.5032	2.39	5-9	98	7	1.9811	11705.09 lbs
88	Alfalfa........	3572	Uniform Clay Loam...	.4798	2.39	5-9	109	10	3.0548	13989.16 lbs
89	Alfalfa........	3572	Uniform Clay Loam...	.5372	2.39	5-8	118	13	3.3388	15022.34 lbs

The preceding tables show the major part of the crop tests that were included in the four seasons' Duty of Water Investigation. These tables give a brief resume of the results that were secured from 415 plots consisting of a total area of 1,842.5 acres devoted to the staple crops commonly grown in South Idaho. The majority of the experiments was conducted with alfalfa and the grains, but all of the staple crops were represented. The four year's investigation, from 1910 to 1913 inclusive, with its broad scope has thrown much new light upon many important irrigation problems. It has proven that many old theories have an utter lack of foundation, has established as facts many other theories and has laid the foundation for many new ones. The chief facts that have been brought out and emphasized by the investigation will be briefly discussed later in the report. The investigation in general has shown that individual experiments cannot be depended upon for conclusions for the reason that the results of crop tests are often affected by external or unknown causes and that only the general average of a large number of results secured under approximately the same conditions should

be used. The experiments included in this investigation, however, have covered four seasons, some of which have been wet and others dry, hundreds of different tracts of different classes of soil planted to different crops have been included, and there is every reason to believe that a general average of such a large number of results secured during these four seasons will be found to be very reliable.

It was found early in the investigation that there was a great variation in the water requirements of the various soils and crops. The soils and crops, however, so far as water requirements are concerned, have seemed to automatically resolve themselves into two classes each, (1) those requiring the least water, and (2) those requiring the most water. The crops belonging to the first class, those requiring the least water, are spring and winter grains, potatoes, and clean cultivated orchards. Those belonging to the second class are alfalfa and other hay and pasture grasses. The soils that require the least water are the medium or clay and silt loam soils of a reasonable depth. This class includes adobe, lava ash, clay loam, and fine sandy soils, or any soil of a reasonable depth that is not porous. The soils requiring the most water are the porous soils, such as the coarse, sandy and gravelly soils. For the purpose of illustration, discussion and comparison, the soils and crops will hereafter be tabulated and discussed in this report under the two above-mentioned classes. The average irrigated soil of Idaho, and of most other western states, falls in the medium or first-mentioned class, the percentage of extremely porous irrigated soils being quite low. The tables and discussions in regard to the medium soils will therefore be of more use and interest than those dealing with the porous soils.

The following tables have been compiled from results secured throughout the investigation with the medium or less porous type of soil. This table is made up (1) by showing the average results secured from all of the alfalfa plots included in the investigation that were grown on medium soil, and (2) by selecting the plot which made the maximum yield from each 15-acre experimental tract, irrespective of the amount of water applied, and forming a general average of the results secured from all of them, some 26 in number. The same method of procedure has been followed with the grains.

Average Results Secured on Clay Loam Soils During Four Years 1910 to 1913, Inclusive.

Description of plots	Crop	No. Plots	Average depth water applied	Average yield per acre	Average yield per acre foot of water
All plots included in investigation......	Alfalfa	79	Feet 2.40	4.91 T	2.04 T
Plots making maximum yield in each exp. irrespective of amount applied...	Alfalfa	26	2.73	5.47 T	2.00 T
All plots included in investigation	Grain	221	1.33	36.38 Bu	27 39 Bu
Plots making maximum yield in each exp. irrespective of amount applied...	Grain	60	1.74	44.92 Bu	25.79 Bu

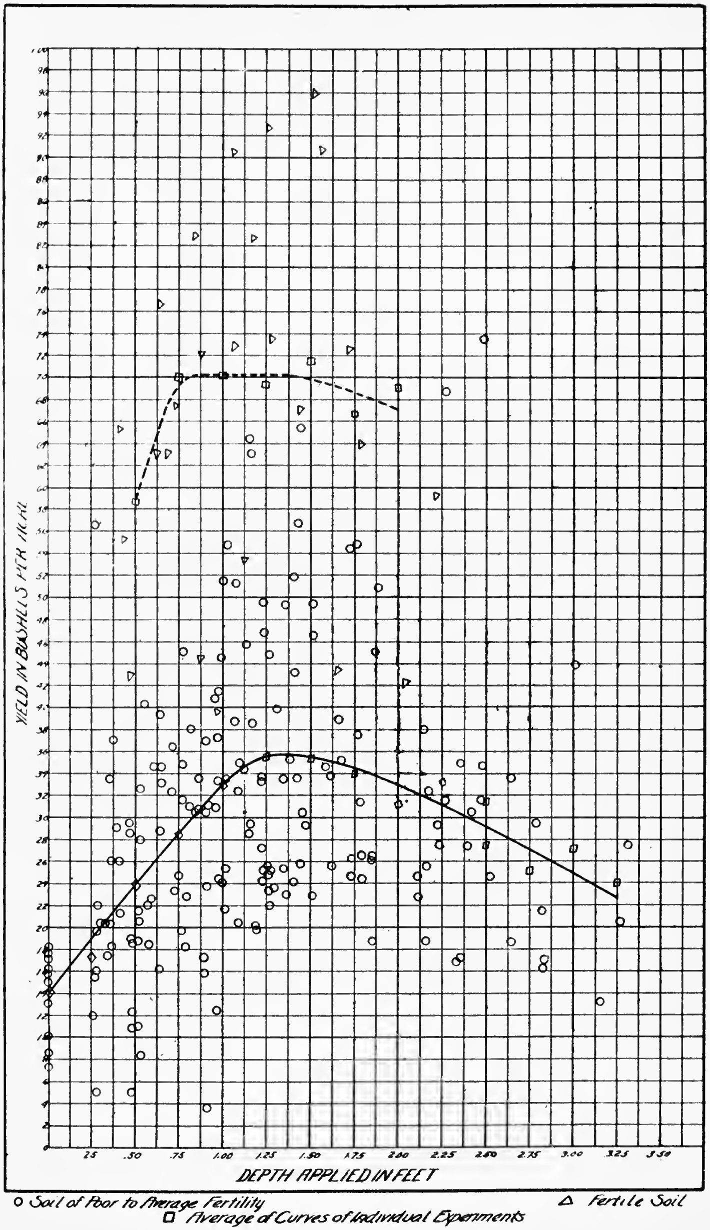
It is believed that the above table will be found both useful and interesting, as it shows (1) the average results secured on clay loam soils from all of the alfalfa plots included in the investigation; (2) the average results on the same type of soil from the alfalfa plots which made the maximum yield in each experiment; (3) the average results secured from all of the grain on clay loam soils included in the investigation; and (4) the average results from the grain plots that made the maximum yield in each experiment on this type of soil.

It will be interesting to note that the second and fourth lines of the table in which are included all of the maximum yields produced, irrespective of the amounts of water applied, show that the maximum yields required considerably more water than was applied to the average of all plots. This strongly indicates that at least up to a certain point the greater amount of water applied, the greater the yield. The last column of the table gives average yield per acre foot of water applied, which is a thorough index of the efficiency secured from the water. It will be noted that, while the most water produced the most crop, the amount of water required to produce the average maximum yield gave less efficiency with alfalfa than the average amount applied to all plots, and that the water required for the maximum yield of the grains was considerably less efficient than the average applied to all plots. Consisting of so many plots which were observed during so many different years the above table should be very dependable, and will no doubt be interesting to irrigation companies and others, many of whom have become too enthusiastic during the last few years over the benefits that are obtained from an abnormally high Duty of water.

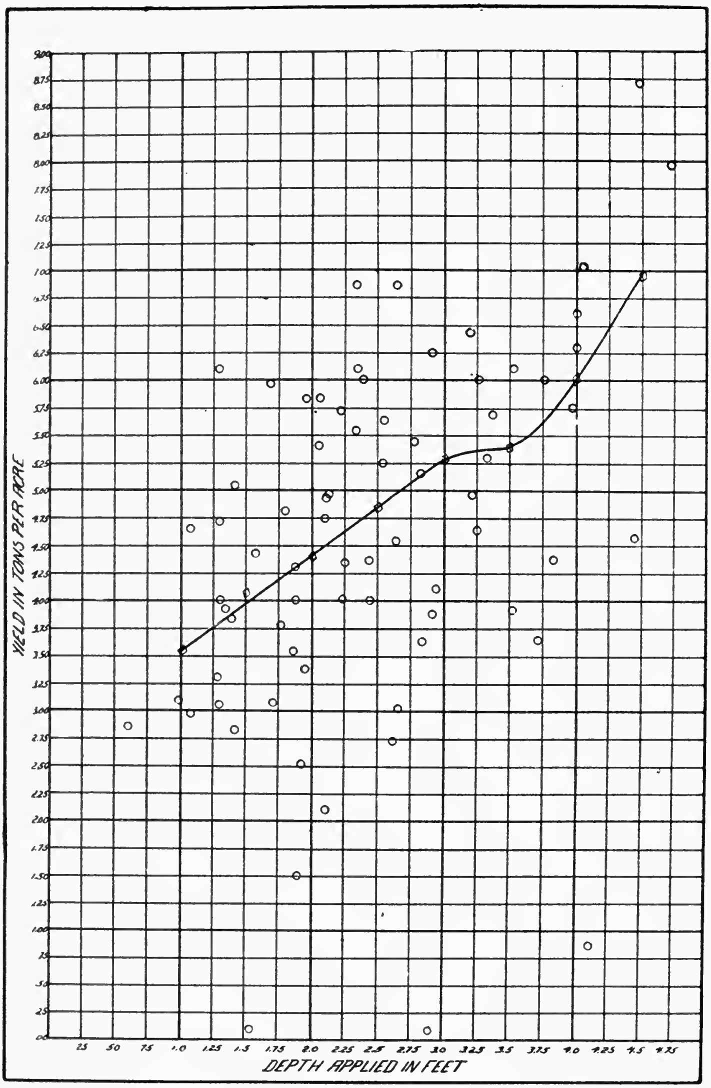
ILLUSTRATION OF ALL RESULTS SECURED ON CLAY LOAM SOILS BY THE MEANS OF CURVES.

The proper interpretation of the results secured has been very difficult at times, for in many cases the results from two different experiments have seemed very contradictory. These freak or erratic, and sometimes unexplainable results are, however, bound to creep into agricultural experiments and serve only to emphasize the value of a broad investigation extending over a number of years. Due to the great variation in the results that have sometimes been secured from even more or less similar experiments, it has been realized that no two men could take even the enormous amount of data that have been gathered in this investigation and arrive at exactly the same results. The ultimate results would be bound to be more or less influenced by personal bias. This would be especially true if the investigator were inclined to be biased in any way, for some experiments show surprisingly large results from a very small amount of water, while others, on the other hand, indicate that abnormally large amounts are required for the production of even a small crop.

In order to show up all of the results in such a way that they may be compared at a glance and in such a manner as to positively and effectually eliminate all personal equation, all of the results secured during the investigation on the medium soils have been plotted as curves and are shown on the two following plates. The two factors which have been considered in plotting these curves are yields per acre and the depths of water applied to produce them. These curves show many factors at a glance, and it is believed will warrant a large amount of careful study.



AVERAGE YIELD FROM DIFFERENT AMOUNTS OF WATER
207 GRAIN FIELDS ON CLAY LOAM SOILS. 1910 to 1913



AVERAGE YIELD FROM DIFFERENT AMOUNTS OF WATER
77 ALFALFA FIELDS ON CLAY LOAM SOILS. 1910 to 1914.

The grain curve shows the yields secured from, and amounts of water applied to, some 207 individual fields. The points are widely scattered, showing that the results secured from any one plot cannot be depended upon, and that only an average of the results from a large number of experiments should be taken into consideration when determining the duty for any particular soil or crop. The grains that have been planted and grown upon soils that have been fertilized either with manure or by the plowing under of alfalfa sod have been plotted as triangles, while those grown upon ordinary or unfertile soils have been plotted as small circles. The grain curve shows strikingly that a much higher efficiency is almost invariably secured from the water when applied to grain planted on rich, fertile soils. While the points, each of which designates one particular field, are widely scattered on the sheet, there are so many of them that it seems reasonable that a curve plotted across the sheet striking an average of the points and showing as near as possible an average of all results would be fair and accurate enough for all practical purposes. Such a line on the grain curve shows that a yield of about 14 bushels per acre was made with no water application, and approximately 36 bushels per acre with an application of 1.5 acre feet per acre, and proves unquestionably that the yield of grain in general may be expected to increase as the water applied is increased until approximately 1.5 acre feet per acre has been applied, after which the curve shows a strong probability that the yields would decrease if more water were applied. It is believed that the results shown on this sheet cannot be questioned or controverted by anyone, for personal equation can have absolutely no bearing on the proposition in any way. These curves show a striking agreement with the result tabulated in the preceding table on page 97, and would seem to prove beyond a doubt that at least 1.5 acre feet per acre are required for grain on the average soils of South Idaho, and that when more water than that is applied there is not only not a proportional increase in yield but there is an actual decrease in yield.

The alfalfa curve also shows a general tendency toward increase in yield as the water applied is increased, there

being no appreciable break in the curve within the limits of the experiments. This curve shows without question that alfalfa requires much larger amounts of water than grain, that a maximum yield requires an abnormally large application, and that there is a strong and regular tendency for alfalfa to increase in yield as the amount of water application is increased from one up to at least four acre feet per acre. This curve also shows a striking agreement with the alfalfa columns in the preceding table. The increase in the yield of the alfalfa, however, is not proportional to the increase in the water applied. A study of the curve would make it appear somewhat doubtful if one would ever be warranted in applying more than three acre feet per acre to alfalfa on the medium clay loam soil.

WATER REQUIREMENTS AT DIFFERENT TIMES DURING THE SEASON.

The foregoing curves are based on all the measurements made, including those in which the crops were evidently injured by the lack of water or by too much water, as well as those in which large quantities of water were used without any appreciable increase in yield. They do not, therefore, necessarily indicate a proper Duty under good practice. Nor do they show the proportion of the water used that was required at different times during the season.

The appropriations and contracts of nearly all of the various irrigation companies and water users in the State call for a continuous flow of a certain number of cubic feet per second throughout the irrigation season. The Duty of Water Investigation, however, has shown very conclusively that the water requirements of all crops or combinations of crops vary greatly at different times during the season, and that a uniform continuous flow from the beginning to the end of the season is not conducive to a high efficiency from the water.

In order to throw light upon this important subject and furnish reliable data for use in designing storage projects and pumping plants where the actual maximum seasonal demand must be known before the economic size of plant or reservoir can be determined upon, the following tables have been compiled from the data secured. All tracts

or plots that have made any appreciable decrease in the yields because of water shortage or excessive application have been eliminated. Other tracts have also been arbitrarily eliminated where an abnormal or unjustifiable increase in the amount of water was required in order to secure a very small increase in the yield, and it is believed that the data in these tables will furnish a basis from which the proper and economic duty for any particular project can be determined.

For convenience and ready comparison four tables have been made of the results secured during the four years, by separating the crops and soils into two classes each, viz: (1) grain on medium clay and sandy loam soils; (2) alfalfa, clover, and pasture on medium clay and sandy loam soils; (3) grain on porous, coarse sandy and gravelly soils; (4) alfalfa, clover, and pasture on porous, coarse sandy, and gravelly soils.

Summary of Depths of Water Applied by Months to One Hundred and Seventy-one Fields of Grain and Alfalfa on Medium Clay and Sandy Loam Soils.

Altitudes ranging from 2400 to 5000 feet. Seasons of 1910, 1911, 1912 and 1913.

Season	No. of plots	April 1-15	April 16-30	May	June	July	Aug.	Sept. 1-15	Total for season
119 Fields of Grain—									
1910	31	......	....	.3210	.6000	.5460	.0780	....	1.5450
1911	30	......	......	0270	.6540	.4780	-.0100	... ..	1.1690
1912	25	.....	......	......	.9420	.6550	0460	....	1.6430
1913	33	......	0392	.2062	.5434	.5941	.2268	....	1.6097
Average	....	......	.0098	.1385	.6849	.5683	.0902	....	1.4917
Per cent of total	....	......	.66	9.28	45.91	38.10	6.05	....	100.00
52 Fields of Alfalfa—									
1910	15	.0600	.0210	.5540	.7390	.6530	.6070	.0650	2.6990
1911	13	......	.0350	.4930	.2930	.9130	.6970	.2480	2.6790
1912	11	......	......	.4910	.5030	.6210	.6080	.0380	2.2610
1913	13	......	......	.8627	.2284	.7422	.3854	.0175	2.2362
Average	....	.0150	.0140	6002	.4408	.7323	.5744	.0921	2.4688
Per cent of total	....	.61	.57	24.31	17.86	29.66	23.26	3.73	100.00

The above tables, as has been stated, include only plots that have demonstrated by the yields produced that they were cultivated and irrigated in the best possible manner, and the average amount applied during the 4-year period is shown at the bottom of the last column of each table. and is that amount which the author deems the best econ-

omic amount for the crop in question when planted on a medium clay loam on average South Idaho soil. The amounts of water tabulated in the above tables are the amounts that have been actually retained upon the fields in question, the waste water having been deducted.

The grain table shows a Duty of almost exactly 1.50 acre feet per acre, of which .0098 acre feet, or .66 per cent are required during the last half of April; .1385 acre feet, or 9.28 per cent during May; .6849 acre feet, or 45.91 per cent during June; .5683 acre feet, or 38.10 per cent during July; and .0902 acre feet, or 6.05 per cent during August, there having been no water required for grains in September during the period covered by the investigation.

The alfalfa table shows a water requirement of 2.4688 acre feet per acre, which is to all intents and purposes 2.5 acre feet per acre, of which .029 acre feet, or 1.18 per cent is required during April; .6002 acre feet, or 24.31 per cent during May; .4408 acre feet, or 17.86 per cent during June; .7323 acre feet, or 29.66 per cent during July; .5744 acre feet, or 23.26 per cent during August; and .0921 acre feet, or 3.73 per cent during the first one-half of September.

It is believed that the two tables immediately preceding will be found the most valuable and most dependable of any that it is possible to include in this report, for they are a general summary of the four years' investigation in Idaho.

Porous soils were included in the investigation during the seasons of 1910 and 1911, and a table which follows later, page 109, shows the average results secured on these soils.

It is believed that the results secured are typical in every way of what might be expected from porous soils and that they may be safely used in such connection. It will be seen from the tables that the amounts required for alfalfa and the grains on these soils bear practically the same relationship to each other as they do when the crops are planted on the medium soils, and that a far larger amount of water is required for the successful irrigation of the crops than is required when they are planted on the medium Idaho soils.

COMPARATIVE AREAS DEVOTED TO DIFFERENT CROPS.

In view of the great difference in the water requirements of (a) the grains, potatoes and clean cultivated orchards, and of (b) alfalfa, the clovers and pasture, it is apparent that a knowledge must be had of the comparative areas that will ultimately be devoted to these different crops before the proper Duty can be determined for any project.

The acreages planted to these crops will, of course, depend in each case upon the soil, climate, proximity to market, and local conditions obtaining in each case, but is best determined by a survey of well developed projects that are and have been operating under normal conditions. It has frequently been assumed by those best informed in regard to irrigation conditions that most of Idaho's projects will be about equally divided between the two above classes of crops, but in order to demonstrate this matter more fully a census has been secured of the acreages of the various crops on the South Side Twin Falls Tract for 1912 and 1913, and of seven Boise Valley canals for 1911 and 1912 . A brief summary of this census is given in the following table. The census of the South Side Twin Falls Project was made by the ditch riders under the supervision of General Manager Harlan, and that of Boise Valley canals was secured by our own assistants.

Table Showing Comparative Areas Devoted to Different Crops.

District	Year	Hay and Pasture		Grain, Potatoes and Orchard		Total—acres
		Area—acres	Per cent of total	Area—acres	Per cent of total	
Twin Falls South Side Project	1912	70,043	47.55	77,266	52.45	147,309
Twin Falls South Side Project	1913	67,115	44 95	82,196	55.05	149,311
Seven Boise Valley Projects	1911	*26,253	*59.75	17,684	40.25	43,937
Six Boise Valley Projects	1912	24,492	57.90	17,804	42.10	42,296
Total	.....	187,903	....	194,950	....	382,853
Per cent of total	......	....	49.08	....	50.92	....

* This area and percentage was somewhat above normal on account of the comparatively large amount of bottom land that was seeded to pasture under some of these canals.

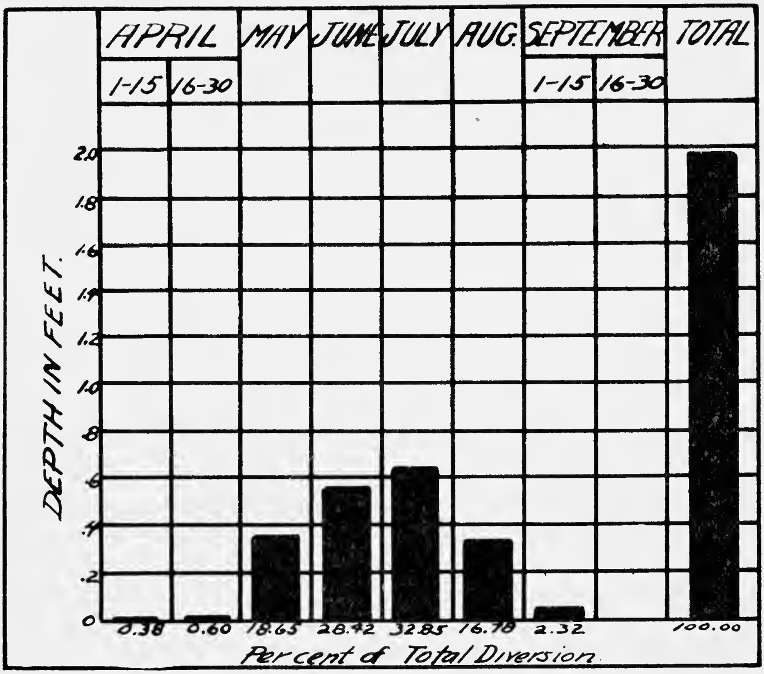
In view of the fact that the percentage shown in the above table agrees with the best information obtainable along this line, it is considered that it is fair to assume that any normal project in South Idaho will ultimately be devoted to approximately equal areas of (1) the grains, potatoes and orchards, (2) alfalfa, clover and pasture, or crops requiring a similar amount of water. Assuming that this will be the case, the average Duty for a normal Idaho project should be found by averaging the proper and economic Duty for the two above named classes of crop on the particular type of soil involved. The following table has been constructed in this manner by averaging the Duty that has been determined for grain and for alfalfa on the medium or average soil of South Idaho for all four years of the investigation.

Summary of Depths of Water in Feet Applied by Months to One Hundred and Seventy-one Selected Fields of Grain and Alfalfa on Medium Clay and Sandy Loam Soils.

Altitude ranging from 2400 to 5000 feet. Seasons of 1910, 1911, 1912, 1913.

Crop	Season	No. of Plots	April		May	June	July	Aug.	Sept. 1-15	Total for season
			1-15	16-30						
Alfalfa	1910	15	.0600	.0210	.5540	.7390	.6530	.6070	.0650	2.6990
Grain.............	1910	31	......	......	.3210	.6000	.5460	.0780	....	1.5450
Alfalfa	1911	13	......	.0350	.4930	.2930	.9130	.6970	.2480	2.6790
Grain.......	1911	30	......	.....	.0270	.6540	.4780	.0100	....	1.1690
Alfalfa	1912	11	......	......	.4910	.5030	.6210	.6080	.0380	2.2610
Grain.............	1912	25	......	......	....	.9420	.6550	.0460	....	1.6430
Alfalfa	1913	13	......	......	.8627	.2284	.7422	.3854	.0175	2.2362
Grain.............	1913	33	......	.0392	.2062	.5434	.5941	.2268	....	1.6097
Average..........	......	....	.0075	.0119	.3693	.5628	.6504	.3323	.0460	1.9802
Per cent of total .	......	....	.38	.60	18.65	28.42	32.85	16.78	2.32	100.00

The above table is a general average of the results that have been secured on the average soil of South Idaho during the entire four years' investigation, and it is considered that it is by far the most important table included in this report. It is in reality the "meat" or final result of the entire four years' Duty of Water Investigation and, as the soil in question is an average of that which is, or will be, included in at least 75 per cent of Idaho's irrigation projects, and probably in the same per cent of the projects in many other states, it is believed that this table will be used far more than the following one which shows the average amounts applied to porous soils.



AMOUNT OF WATER REQUIRED EACH MONTH OF THE IRRIGATION SEASON BY A PROJECT DEVOTED TO EQUAL AREAS OF GRAIN AND HAY ON MEDIUM CLAY OR SANDY LOAM SOIL.

As this table includes the results of 171 *selected* tracts of this particular type of soil covering a period of four years, thus effectively eliminating the individual differences of the seasons, of irrigators and of the tracts themselves, it is considered that the results contained in it will be found to be very dependable.

It shows that a project devoted to equal areas of (1) grain, orchards, and general root crops, and (2) hay, including alfalfa, clover, timothy and pasture on average South Idaho soil should furnish sufficient water so that an average of 1.98 acre feet can be *retained* on each and every irrigated acre during the season. Of this amount, which is to all intents and purposes an annual or seasonal Duty of 2 acre feet per acre, *exclusive* of the precipitation, 0.0075 feet in depth or 0.38 per cent will be required during the first half of April; 0.0119 feet in depth or 0.6 per cent will be required in the last half of April; 0.3693 feet in depth or 18.65 per cent during May; 0.5628 feet in depth or 28.42 per cent during June; 0.6504 feet in depth or 32.85 per cent during July; 0.3328 feet in depth or 16.78

per cent during August; and 0.0460 feet in depth or 2.32 per cent during the first half of September, making a total of 1.9802 acre feet per acre, or 100 per cent for the season. The above amounts are based strictly upon the crop needs as shown by the Duty of Water Investigation, and includes nothing for stock water or that which may be required for domestic purposes or for losses in conveyance, nor is there any included for late fall or winter irrigation. If the data in this table are to be used in alloting water to an irrigation project this factor must be taken into consideration, if water is to be used for the above mentioned purposes.

This table shows that there is small need for water either earlier than May or later than August; and that in all of the tracts considered there has been no need for water during the four years of the investigation by either alfalfa or grain during the last half of September. It shows also that over 61 per cent of the total water required during the season is required in the 61 day period during June and July. This table will be found very useful to those called upon to design storage projects, as a variety of curves may be worked up from it, which, taken in connection with the hydrograph of the discharge of the stream from which the supply is to be derived, will show how much of the water it will be necessary to store. It will also be of great help in the designing of pumping plants, and particularly in determining the size of the various pumping units that should be installed.

The table shows conclusively that any large pumping plant should consist of more than one unit, and possibly as many as three or four, for a unit that could economically supply the maximum demand during June and July could not possibly be economically operated with the decreased demands of May and August. This feature must always be given consideration.

The table seems to prove conclusively that the uniform continuous flow method of delivery is exceedingly wasteful, for if a right called for a uniform continuous flow throughout the season with an allotment per acre of sufficient size to deliver the required amount during June and July, a large proportion of the amount delivered could not be used economically, and would be wasted during the months of April, May, August, and September. While if,

on the other hand, the uniform continuous flow were of the size required to deliver the 2 acre feet required during a 6 months' or even a 4 months' irrigation season, there would still be more water than is actually required during the early and late part of the season, and considerably less than is required during the months of June, and July, when 61 per cent of the total season's supply must be delivered if profitable returns are to be expected.

The following table gives a general summary of the results that have been obtained upon the porous sandy and gravelly soils. This table has been constructed by averaging the Duty that has been determined for grain and alfalfa on these soils during the first 2 years of the investigation, there not having been a sufficient number of tracts on this type of soil experimented upon during the last 2 years of the investigation to be included in such a summary table.

Summary of Depths of Water in Feet Applied by Months to Thirty-one Selected Fields of Grain and Alfalfa on Porous Sandy and Gravelly Soils.

Altitudes ranging from 2600 to 5800 feet. Seasons of 1910 and 1911.

Crop	Season	No. of plots	April 1-15	April 16-30	May	June	July	Aug.	Sept. 1-15	Total for season
Alfalfa	1910	7	......	.5310	1.1200	1.6910	1.9570	1.1310	....	6.4300
Grain	1910	10	......	......	.0290	1.4430	.6550	.3580	....	2.4850
Alfalfa	1911	6	......	.1820	.9160	1.8430	1.1150	2.2650	.2560	6.5770
Grain	1911	8	......	......	......	.8980	1.0570	.9430	....	2.8980
Average..........	......	....	......	.1782	.5163	1.4687	1.1960	1.1743	.0640	4.5975
Per cent of total.	......	....	......	3.88	11.23	31.95	26.01	25.54	1.39	100.00

This table shows that porous soils require a larger amount for their efficient irrigation than the medium soils, and indicates that a Duty of approximately 4.6 acre feet per acre per annum will be required, of which 3.88 per cent will be required during the last half of April; 11.23 per cent will be required during the month of May; 31.95 per cent during June; 26.01 per cent during July; 25.54 per cent during August; and 1.39 per cent during the first half of September, making a total of 4.5975 acre feet, or 100 per cent during the season.

The preceding tables showing the average Duty that has been arrived at for projects with either medium or porous soils are considered the most important in the report.

These and the many factors which have a bearing upon the Duty of Water will be discussed more thoroughly later in the report.

INVESTIGATION OF USE OF WATER UNDER COMPLETE CANAL SYSTEMS IN BOISE AND UPPER AND MIDDLE SNAKE RIVER VALLEYS.

It is considered that the investigation which has been carried on will furnish a very accurate idea of the proper and economic field Duty for the different soils, but it has been realized that, in addition to this, a knowledge of the losses that are usually experienced in transmitting and delivering the water must be had before it will be possible to design an efficient and economical project. In order to secure a better knowledge of this factor it was decided to extend the investigations by measuring the total amount of water diverted by several typical large canals and then secure the acreage under them devoted to the different crops, and in this way determine the gross amount that it is found necessary to divert for the irrigation of large areas under normal conditions, where waste water and that used for domestic purposes, etc., would all be considered.

It had been planned to do this work during 1912, along with a lesser number of the usual Duty of Water experiments, as a rounding out of the entire investigation, but it was found in the fall of 1911 that the local branch of the U. S. Reclamation Service had been making a careful measurement of all water diverted by the principal canals of the Boise Valley during the season, and it was decided to start this line of investigation at once, provided a suitable arrangement could be entered into with the U. S. Reclamation Service for securing these measurements. These arrangements were perfected and an agreement was entered into between the two departments, whereby our department was to make a careful canvass of the crop acreages under the canals and exchange the data so collected with the U. S. Reclamation Service for the discharge tables that had been secured by them.

Accordingly, an experienced man was placed in the field, who made a careful and painstaking canvass of the areas devoted to the different crops, together with the unirrigated area, and such other data as was thought necessary. This crop census was made of all lands under the

following canals: Settlers', Farmers' Co-operative, Riverside, Farmers' Union, Pioneer, Eureka and Boise Valley.

On account of the great expense that would have been involved in making a survey, the acreages were obtained by a careful and systematic house-to-house canvass or census. It is believed that this canvass was especially accurate and fully as reliable as any stadia survey that could be made, for the following reasons:

(1) A much larger area could be taken into consideration on account of the expense that would be involved by a survey, which increase in area, it is believed, materially reduced the percentage of error from all causes.

(2) Accurate maps of the canal systems were secured, and as the farms were regular in shape and not cut up by waste land, the total area under the canals was easily secured.

(3) The areas devoted to individual crops were obtained from the farm operators on the ground, and as the areas of the individual crops had to equal the total area of the farm, in each case a very good check was obtained upon the accuracy of the canvass.

Water Measurements.

All water measurements during 1911 were made by the local branch of the U. S. Reclamation Service. Those of 1912 were made by our own hydrographers. The discharge of the canals has been calculated from daily gauge readings and rating curves, which were made up from a large number of current meter measurements made by from two to six hydrographers at each station. These rating stations were very carefully selected, and as a very large number of careful ratings were made at each station, it is believed the discharge tables given herein are very accurate. The water measurements of the South Side Twin Falls Canal were secured from the local branch of the U. S. Geological Survey, and the crop census from General Manager Geo. Harlan, who had caused a census to be taken during both years by his ditch riders. A brief description of each canal system follows, together with the data that were secured from it during the seasons of 1911 and 1912.

Riverside Canal.

The Riverside Canal diverts water from the south side of the Boise River just above Caldwell. This canal irrigates approximately 9,000 acres of bench lands, consisting

principally of the typical volcanic ash or clay loam soil common to the greater portion of South Idaho.

Farmers' Co-Operative Canal.

The Farmers' Co-operative Canal diverts water from the north side of the Boise River just above Caldwell, the the headgate being located almost opposite that of the Riverside Canal. The canal has a total length of about 28 miles and irrigates bench lands entirely. The soil under this canal varies from a clay loam to a loose granite sand.

Farmers' Union Canal.

The Farmers' Union Canal diverts water from the north side of Boise River near the Soldiers' Home, a short distance below Boise. The soil under this canal is mostly volcanic ash or clay loam, there being a small percentage of somewhat sandy soil. This canal is approximately 20 miles in length and irrigates approximately 7,000 acres of land.

Settlers' Canal.

The Settlers' Canal diverts its water from the south side of Boise River within the city limits of Boise and irrigates approximately 12,000 acres of clay loam bench land in the vicinity of Meridian on the south side of Boise River.

Boise Valley Canal.

The Boise Valley Canal diverts its water from the Farmers' Union Canal about one mile below the intake of that canal and furnishes water for approximately 2,600 acres of sandy loam bottom lands. The ground water under practically all of this land rises every summer and averages from two to four feet from the surface during the irrigation season.

Pioneer Canal.

The Pioneer Canal diverts water from the north side of the Boise River about one mile southeast of Palmer Station. This canal is only approximately three miles in length and furnishes water for approximately 1,265 acres of sandy loam Boise bottom lands. The land under this project is fairly well irrigated during the irrigation season by sub-irrigation from the rise of ground water.

Eureka Canal.

The Eureka Canal diverts water from the south side of

Boise River immediately below the headgate of the Phyllis Canal. This canal supplies water for approximately 2,000 acres of Boise bottom land and is very similar in every respect to the Pioneer Canal.

Randall Canal.

This canal diverts its water from the Burgess Canal 7 miles southwest from Rigby in the upper Snake River Valley. It is about five and one-half miles in length and furnishes water for approximately 4,000 acres. The lands under the canal have a uniform topography and the soil is of a very porous, gravelly nature, common to 30,000 or 40,000 acres in that vicinity.

Clark and Edwards Canal.

The Clark and Edwards Canal diverts water from the "Big Feeder" about six miles southeast from Rigby. This canal is approximately four miles in length and furnishes water for about 4,000 acres of very gravelly land.

South Side Twin Falls Canal.

This well known canal diverts water from the south side of Snake River at Milner through a main canal with a capacity of 3,200 cubic feet per second, and 25 miles long. The main canal branches into two main branches at the end of the 25 mile section, each branch being approximately 35 miles in length. The South Side Twin Falls Project consists of approximately 200,000 acres of slightly rolling clay loam or lava ash soil situated on the south bank of Snake River and east of Salmon River. The project has a rather uniform topography with a slope averaging 50 feet per mile to the northwest. The soil varies in depth from 2 to 40 feet with a probable average of 6 to 10 feet, being underlaid with lava rock, there being no intervening stratum of gravel or other porous material. The first irrigation water was applied to this project during the seasons of 1905 and 1906, the following tables showing the amount cultivated during the seasons of 1912 and 1913.

Table Showing Comparative Area Devoted to Different Crops, of Areas Actually Irrigated Under Ten Different Canals.

Name of canal	Year	Hay		Pasture		Grain		Orchard*		Total acres
		Acres	Per cent	Acres	Per cent	Acres	Per cent	Acres	Per cent	
Riverside	1911	4059.00	54.7	175.25	2.4	911.00	12.2	2280.25	30.7	7425.50
Riverside	1912	3455.75	50.1	627.25	9.1	1360.00	19.7	1455.50	21.1	6898.50
Farmers' Co-operative..	1911	5526.75	44.4	1626.00	13.1	2043.50	16.4	3239.00	26.1	12435.25
Farmers' Co-operative..	1912	4890.00	37.4	2289.50	17.5	2354.25	18.0	3528.66	27.1	13062.41
Farmers' Union.........	1911	3339.44	48.8	1171.94	17.1	1526.94	22.3	804.38	11.8	6842.70
Farmers' Union.........	1912	3045.35	42.6	1534.74	21.5	1737.00	24.3	827.33	11.6	7144 42
Settlers'.....................	1911	4385.25	37.1	2157.25	18.2	3686.50	31.2	1590.80	13.5	11819.80
Settlers'.....................	1912	4490.25	38.2	1848.20	15.7	3294.75	28.0	2121.80	18.1	11755.00
Boise Valley.............	1911	332.25	14.9	1189.09	53.4	277.80	12.5	426.35	19.2	2225.49
Boise Valley.............	1912	267.00	11.7	1222.50	53.4	336.0	14.7	461.50	20.2	2287.00
Eureka.....................	1911	369.00	17.9	1138.75	55.2	505.00	24.5	49.25	2.4	2062.00
Pioneer.....................	1911	115.25	10.2	667.67	59.3	197.90	17.6	145.72	12.9	1126.54
Pioneer.....................	1912	132.50	11.5	689.32	60.0	166.75	14.5	160.17	14.0	1148.74
Randall....................	1912	1193.50	36.6	207.50	6.4	1145.00	35.2	709.00	21.8	3255.00
Clark and Edwards.....	1912	570.00	41.9	97.00	7.1	463.50	34.0	232.00	17.0	1362.50
South Side Twin Falls	1912	59229.00	40.2	10094.00	6.8	56379.00	38.3	21607.00	14.7	147309.00
South Side Twin Falls	1913	54903.00	36.8	12212.00	8.2	60805.00	40.7	21391.00	14.3	149311.00
Total..................	....	150303.29	....	38947.96	....	137189.89	....	61029.71	....	387470.85
Average per cent......	....	....	38.8	....	10.1	....	35.4	....	15.7	100.00

* Includes small fruit, garden, potatoes, and home grounds.

Table Showing Acre Feet Diverted Per Acre Irrigated Each Month of Irrigation Season for Ten Different Canals.

Name of canal	Year	Acre-feet diverted per acre irrigated: April 1-15	April 16-30	May	June	July	Aug.	Sept.	Oct. 1-15	Oct. 16-31	Total
Riverside	1911	0.08	0.43	1.40	1.46	1.54	0.79	0.79	0.50	0.15	7.14
Riverside	1912	0.11	0.63	1.74	1.98	1.99	1.19	1.23	0.62	0.00	9.49
Farmers' Co-operative	1911	0.04	0.38	1.31	1.36	1.16	0.44	0.36	0.28	0.19	5.52
Farmers' Co-operative	1912	0.00	0.08	1.07	1.26	0.94	0.58	0.56	0.17	0.10	4.76
Farmers' Union	1911	0.14	0.48	1.25	1.41	1.25	0.55	0.45	0.13	0.00	5.66
Farmers' Union	1912	0.25	0.68	1.32	1.23	1.07	0.53	0.45	0.00	0.00	5.53
Settlers'	1911	0.04	0.16	0.42	0.72	0.71	0.46	0.42	0.11	0.00	3.04
Settlers'	1912	0.00	0.01	0.49	0.69	0.70	0.54	0.34	0.10	0.00	2.87
Boise Valley	1911	0.14	0.27	0.63	0.59	0.64	0.42	0.30	0.12	0.00	3.11
Boise Valley	1912	0.00	0.00	0.46	0.50	0.68	0.38	0.37	0.00	0.00	2.39
Eureka	1911	0.00	0.05	0.38	0.33	0.34	0.35	0.34	0.03	0.02	1.84
Pioneer	1911	0.11	0.40	0.91	0.97	1.09	1.01	0.83	0.12	0.00	5.44
Pioneer	1912	0.14	0.00	1.12	1.62	1.03	0.98	0.82	0.31	0.00	6.02
Randall	1912	0.00	0.00	0.00	1.58	2.25	1.99	0.81	0.25	0.00	6.88
Clark and Edwards	1912	0.00	0.00	0.31	2.59	3.00	2.67	2.04	0.34	0.00	10.95
South Side Twin Falls	1912	0.10	0.14	0.60	1.10	1.23	1.13	0.61	0.22	0.16	5.29
South Side Twin Falls	1913	0.09	0.11	0.83	1.12	1.25	1.21	0.73	0.20	0.17	5.71
Average for month	....	0.08	0.22	0.84	1.21	1.23	0.89	0.67	0.20	0.05	5.39
Per Cent of Season's Diversion	....	1.49	4.08	15.60	22.43	22.83	16.5	12.43	3.71	0.93	100.00

The Boise Valley canals included in the foregoing investigation are fairly well distributed throughout the valley, supply water to a large percentage of its irrigated area, and there is no doubt but that the tables represent the present average use of water in the Boise Valley. The Clark & Edwards and the Randall Canals lie in the upper Snake River Valley but are not typical of the majority of the canals in that district, for the soil under them is more gravelly than the district as a whole averages. These canals and the use of water under them, however, are typical of those supplying water for some 40,000 or 50,000 acres in the vicinity of Rigby. The use of water under the South Side Twin Falls Canal is probably typical of the majority of Idaho's largest irrigation projects, particularly of those which have a large and adequate water supply.

It is regretted that the data secured do not throw any light on the losses that have been experienced by seepage under the projects investigated. The study of the data included in the tables makes it quite evident that this factor is much greater than is usually believed. From a study of the seepage measurements which are described later in this report it would seem that the transmission losses of Idaho canals range from 20 per cent to as high as 50 per cent of the water diverted.

The water supply in the Boise River is usually plentiful for all canals until the middle of July, after which time a reduction in the amounts diverted is made by the water master on all except those having the earliest priorities. For this reason the amounts shown as having been diverted by the Boise Valley canals during August, 1911, are unquestionably from 20 to 30 per cent below the amounts needed. The flow of the Boise River, however, was above normal during August, 1912, and it is believed that the canals during that month diverted all of the water that was actually required. A comparison of the above tables of canal diversions with the preceding curve and Duty tables strikingly emphasize many interesting factors:

(1) That where water supply is plentiful the average canal diverts more water than is needed for economical irrigation, both at the beginning and end of the irrigation season.

(2) That practically the entire need for water falls during the four months from May to August, inclusive.

(3) That the actual diversion of average canals is far greater than many have realized, indicating that the loss from seepage, evaporation, general waste and careless use as well as the amount required for stock and domestic purposes is far greater in actual practice than has usually been acknowledged. A careful study of the above data taking into consideration the fact that the canals investigated represent an average or a little better than average use of water, makes it evident that there is grave danger of allotting insufficient water to many of our future projects.

AMOUNT OF WATER USED ON TYPICAL FARMS UNDER THE RIDENBAUGH CANAL IN THE BOISE VALLEY DURING THE SEASON OF 1912.

It is believed that the average results of the Duty of Water Investigation with its variation of water on all tracts will give the correct Duty, but as only approximately one-third of the tracts involved have been handled exclusively by the owners themselves it is realized that the results that have been secured may not furnish an accurate idea of the average use of water in the State at this time. In order to show the average use of water in a typical district and to furnish data to strengthen the other more exact Duty of Water experiments where the water had been varied and measured very carefully, it was decided to detail one assistant during the irrigation season of 1912 to the measurement of the water used by the farmers on as many farms as possible in a typical district.

The district selected was that lying under the Ridenbaugh Canal within a radius of four miles of Meridian. Care was used to include as many as possible of the staple crops on the average farms of the district, and as much was included as one man could cover, reading all weirs in the supply ditches twice daily. The waste water was not measured, but all of the areas were surveyed very carefully. There were no restrictions whatever placed upon the users, and it is believed that the customary amount of water was used, and that an average crop was produced. The data secured are given in the following table:

Table Showing Amount of Water Used on Typical Farms Under the Ridenbaugh—a Boise Valley Canal—During the Season of 1912.

Number	Crop	Area in acres	Date of first and last irrigation	Ir. season—days	No. of irrigatn's	Depth per acre —feet	Yield per acre	Remarks
1	Alfalfa	3.50	5-14— 9-18	128	10	5.6619	5.92 tons	
2	Alfalfa	5.31	5-13— 8-29	109	6	3.3961	4.67 tons	
3	Alfalfa	7.06	5-15— 9-2	111	6	3.2617	4.67 tons	
4	Alfalfa	26.25	5-16— 9-8	116	6	3.3747	3.19 tons	
5	Alfalfa	6.78	5-21— 9-9	112	6	3.7999	3.63 tons	
6	Alfalfa	7.68	5-18— 9-14	120	6	4.0183	3.63 tons	
7	Alfalfa	10.32	5-26— 9-15	113	7	3.0995	3.58 tons	
8	Alfalfa	7.24	5-21— 8-20	92	5	2.7191	3.25 tons	Two cuttings.
9	Alfalfa	5.85	5-16— 8-20	97	3	3.1101	3.42 tons	
0	Alfalfa	3.85	5-18— 9-25	131	6	2.2104	3.00 tons	
1	Alfalfa	1.42	5-19— 7-11	54	3	4.6274	3.25 tons	Two cuttings, carelessly irrigated.
2	Alfalfa	2.65	5-20— 8-25	98	5	2.3187	1.92 tons	
3	Alfalfa	15.67	5-16— 9-21	129	8	2.4656	3.05 tons	
4	Oats	30.33	6-17— 7-18	32	2	1.0445	55.00 bu.	
5	Oats	19.32	6-12— 7-28	47	3	1.7293	53.67 bu.	
6	Oats	33.70	6-23— 7-28	36	2	1.0853	51.93 bu.	
7	Oats	27.96	6-26— 7-17	22	2	0.8763	32.19 bu.	
8	Oats	14.58	6-26— 8-10	46	3	1.0869	40.81 bu.	
9	Oats and Wheat	11.90	6-8 — 7-26	49	3	1.3572	44.00 bu.	
0	Wheat	16.52	6-20— 8-5	47	3	1.1993	17.92 bu.	Poor land and poorly cared for.
1	Wheat	2.97	6-5 — 7-28	54	3	1.8864	44.00 bu.	
2	Wheat	11.66	7-4 — 7-17	14	1	0.7586	18.00 bu.	Very much neglected.
3	Winter Wheat	11.24	5-30— 6-4	6	1	0.6185	22.42 bu.	
4	Clover	8.66	5-16— 9-25	133	5	3.3567	2.57 tons	Poor stand.
5	Clover	1.96	5-18— 9-29	135	6	3.6594	5.74 tons	Two crops.
6	Timothy	5.11	5.15— 9-20	129	8	3.5761	2.74 tons	One crop (yield baled).
7	Orchard Grass	3.67	5-10— 9-23	137	6	2.9250	2.18 tons	One cutting.
8	Pasture	6.73	5-11—10-1	144	10	2.6943	....	
9	Pasture	7.15	5-8 — 9-25	141	7	3.8111	....	
0	Pasture	4.80	5-12— 9-12	124	6	5.2770	....	Blue grass and white clover.
1	Pasture	3.18	5-9 — 9-26	141	9	3.4493	....	Blue grass and white clover.
2	Apple Orchard	14.39	7-6 — 8-29	55	4	1.3365	....	Three years old.
3	Apple Orchard	33.56	6-22— 9-7	78	3	1.5505	217.94 bxs.	One-half bearing.
4	Apple Orchard	32.04	7-8 — 9-5	60	3	0.7081	....	Clean cultivated, 2 and 3 years ol
5	Apple Orchard	15.43	7-6 — 9-1	58	3	1.4310	....	Clean cultivated, 2 and 3 years ol
6	Wheat and barley	8.20	5-29— 7-19	52	4	0.8969	36.95 bu.	

It is realized that the data secured and tabulated in the above tables are less accurate than those of the major investigation, but in view of the comparatively large area involved, the fact that one man gave his entire time to the investigation during the season and that this man had the entire co-operation of all of the owners, it is believed that the data secured are accurate enough for all practical purposes, and that they will furnish a clear idea of the

average use of water in a typical irrigated section of Idaho. There was no U. S. Weather Bureau Station located at Meridian, but the precipitation that occurred from April to September, inclusive, was without a doubt approximately the same as that of Boise, which is only 9 miles away. This was 8.25 inches.

It is believed that irrigation is as highly developed, and that water is of as much value, in this locality as it is in any other representative district of the same area in the State. It is also believed that the farmers use the water as carefully and waste as little as they do in any other district of the same magnitude. The average of the amounts used by all of these irrigators was 2.56 acre feet per acre, the water having been measured in each case within a short distance of the boundaries of the farms in question. The above use of water agrees very closely with the requirements shown by the major investigation, for if 21 per cent of the amount delivered and applied was wasted, the amount retained would have been almost exactly 2 acre feet per acre. The crops produced that season in the district under observation were fair and normal in every respect. It was the belief of the owners that they could not have well used any less water, and that if less water had been used the yields would have been materially reduced. It is therefore believed that this supplementary investigation furnishes strong and added proof of the adequacy of, and the necessity for, a water right of sufficient size to permit of the retention of 2 acre feet per acre upon clay loam soils.

INVESTIGATION OF THE AVERAGE USE OF WATER BY THE SETTLERS OF THE SALMON RIVER PROJECT.

Three assistants were detailed to the Salmon River Project during the season of 1913, whose entire time was devoted to the measurement and variation of the water applied to 12 tracts of the staple crops, each of an approximate area of 15 acres. Each of these tracts was divided into 3 approximately equal parts. The investigation as above outlined was carried on in order to ascertain the best Duty for the various crops on the project as a whole, for it was believed that the variation of the water would throw new light upon the actual water requirements of the soils and crops.

In order to supplement the experiments where the water was varied and determine the average use of water by the Salmon River settlers and to throw as much additional light upon the proper Duty of Water as possible, one man was detailed during the same season to the measurement of the water applied by the owners to parts of 12 typical ranches well scattered over the project. This was done with 16 automatic water registers, which were installed on weirs in the feed and waste ditches leading to and from each plot. These water registers consisted essentially of an eight day clock and a revolving cylinder upon which a paper record sheet was placed. The variation of the height of the water flowing over the weir and the movement of the clock traced on the record sheets an accurate and continuous record of the height of the water flowing over the weirs, each record lasting an entire week.

Wherever a tract of sufficient area could be picked out so that all of the feed water applied to and all of the water wasted from the tract could be measured by two water registers, this was done, but in cases where the area involved was too small to justify the expense, or where the water wasted from the field in question through 2 different ditches, the waste from the fields was not measured. With one or two exceptions it is believed that the results secured show up the average use of water on the Salmon River Project during the season of 1913. On account of the size of the tracts involved and the wide area which they covered it was found impractical to weigh the yields produced. These were determined from the records of the automatic weighers attached to the threshing machines which threshed the grain, and by measuring the alfalfa in the stack.

While the determinations of yields by the above methods were not absolutely accurate, it is believed they are sufficiently so for all practical purposes. All of the areas involved were carefully surveyed with transit and chain, so that part of the following table which shows depths applied per acre is believed to be very accurate.

Table Showing Amount of Water Applied To and Yields Produced Upon Fields Aggregating 978.22 Acres on the Salmon River Project—Season of 1913.

Number	Name and location	Depth of soil	Kind of crop	Area—acres	Total acre-feet Applied	Total acre-feet Wasted	Depth in feet or acre ft. per acre applied to land	Yield per acre
1	E. V. Johnson, 5 M. N. W. of Berger...	Medium....................	Alfalfa...........	71.27	247.71	......	3.48	3 tons
			Oats...............	45.54	95.09	......	2.09	55 bu. est.
2	Fred Haggard, 3 M. S. of Berger......	Medium and Thin.........	Potatoes..........	38.82	90.09	......	2.32	79.8 sacks
3	Dodd Bros, 2½ M. E. of Berger.........	Deep.........................	Alfalfa...........	18.96	100.40	......	5.30	3.13 tons
			Pasture...........	7.96	33.27	......	4.18	
4	Lincoln & Green ranches, 7 M. N. W. of Berger	Medium and Thin.........	Wheat............	135.89	267.51	......	1.97	21.12 bu.
			Oats...............	102.53	201.84	......	1.97	14.34 bu.
			Beans.............	37.98	74.77	......	1.97	Eaten by rabbits.
			Barley............	6.50	12.80	......	1.97	32.30 bu.
			Burnt Spots.....	6.78	13.35	......	1.97	
5	C. E. Holderman, 2½ M. N. W. of Hollister	Mostly Deep, Some Thin	Young Orchard.	38.40	46.62	......	1.21	
			Potatoes..........	32.76	46.76	......	1.43	32 sacks.
6	Carl Washburn, 3 M. N. W. of Hollister	Deep.........................	Alfalfa...........	21.62	76.66	13.17	2.94	4.12 tons.
7	J. B. Burroughs, 2¾ M. N. W. of Hollister	Deep and Thin............	Wheat............	35.81	53.60	......	1.50	14.5 bu.
8	Salmon River Water Co., adjoining Hollister	Medium and Thin.........	Alfalfa...........	20.57	80.64	9.46	3.46	1.59 tons.
			Alfalfa...........	17.15	16.92	2.24	.86	1.59 tons.
9	Isaac Willis, 1¾ M. E. of Rogerson....	Medium and Thin.........	Wheat............	62.91	95.55	......	1.52	35 bu. est.
			Oats...............	86.74	131.74	......	1.52	45 bu. est.
10	J. F. Emery, 2 M. W. of Rogerson.....	Medium and Thin.........	Wheat............	20.00	15.42	......	.77	22.02 bu.
			Wheat............	28.82	42.04	......	1.46	22.02 bu.
			Barley............	6.21	9.06	......	1.46	40.25 bu.
			Oats...............	4.14	6.04	......	1.46	36.23 bu.
			Potatoes..........	.87	1.27	......	1.46	86 sacks.
11	John Workman, adjoining Amsterdam	Medium......................	Oats...............	40.80	51.03	8.61	1.04	31.32 bu.
			Wheat............	38.24	47.83	8.07	1.04	26.15 bu.
			Pasture..........	5.23	19.37	4.07	2.93	
			Clover............	17.10	59.01	13.29	2.67	
			Potatoes..........	6.34	14.17	2.82	1.79	63 sacks.
			Garden...........	1.41	2.96	.77	1.55	
12	J. A. Henstock, ½M. N. of Amsterdam	Deep and Some Thin.....	Alfalfa...........	20.87	79.44	......	3.81	2.17 tons.

INVESTIGATION OF USE AND DUTY OF WATER AND COST OF PUMPING UNDER ELECTRICAL PUMPING PLANTS IN THE VICINITY OF WEISER AND PAYETTE DURING THE SEASON OF 1913.

Water is now being pumped in Idaho for the irrigation of many thousands of acres, but there are still many opportunities for expansion along this line. This is particularly true of the territory along Snake River from Hagerman as far down as Huntington, Oregon, a distance of nearly 250 miles, there being available even at low water fully 3,000 cubic feet per second of unappropriated water in this section of Snake River. This water cannot be diverted by gravity on account of the comparatively high banks and flat grade of the river, but there is considerable good land adjacent to the river upon which this water might be, and is being pumped with lifts, varying between 50 and 200 feet. The lands adjacent to Snake River, however, are not all of those upon which pumping may be found feasible, for the best land in many projects lies immediately above the high line canals, where in many instances rather large acreages could be covered with comparatively small lifts. Idaho has great water power resources, only a small part of which have been as yet developed, and considering this fact, and the availability of land and water, it appears as though this were a most favorable field for irrigation pumping.

The entire Duty of Water investigation, up until 1913, had been carried on under gravity canals where there was no particular incentive to save water, and it seemed as though the time were opportune to conduct two investigations in one by determining (1) the Use and Duty of Water under a number of pumping plants where there was a strong underlying incentive to secure the highest possible Duty, and (2) to determine the costs of pumping at the same time. There were 163 different electrically driven irrigation pumping plants being operated during the season of 1913 in the territory adjacent to the Snake River between Caldwell and Huntington, and it was decided to assign one assistant to this territory who should be furnished with a motorcycle and who would determine by means of weirs, water registers and watt meters the amount of water pumped and electricity used, under as many as possible of the smaller or medium sized pumping plants in that vicin-

ity. After looking over the territory a number of owners and operators were interested in the investigation and some 20 plants in the vicinity of Payette and Weiser, Idaho, and Ontario, Oregon, were selected for the season's test. Some of the plants selected were paying for their power by the meter rate, and some were paying a flat rate based on the horsepower of their motors. The flat rate plants did not all have meters and it was not possible to determine the exact amount of current consumed by them, but the cost of the service to the farmers for the season, however, based on the amount paid to the power company, was easily determined, and the following tables give the results that were secured. The cost of pumping, as given in these tables, includes only power charges, nothing having been added for depreciation, attendants, etc.

Table Showing Costs of Pumping Season of 1913.

Number	Owner's name	Power		Lift—feet	Acres irrigated	Total No. hrs May to Sept. inc., 3,672		Acre-feet pumped		Rate—Meter or flat	Total cost of power for season	Cost of power		
		Horse power	Kind			Total hours operated during season	Per cent of season operated	Total	Per acre			Per acre	Per acre foot	Per foot—acre foot
1	W. T. Ashunhurst	3	E. Motor	7.12	25.94	2,549	69½ +	155.44	5.99	Flat	$ 84.00	$ 3.24	$ .54 +	$.07½
2	August Brockman	12	Gas Eng.	19.26	30.00	497	13½ +	34.82	1.16	Gas and oil.	129.15	4.31 +	3.71	.19 +
3	A. Diedrickson	3	E. Motor	6.90	45.00	1,372	37⅓ +	88.87	1.97	Meter	79.66	1.77	.90 +	.13 +
4	Geo. Fonner	5	E. Motor	* 15.23 * 21.75 * 22.26	14.42	551	15	22.11	1.53	Meter	100.90	7.00	4.56	.23 +
5	H. E. Golden	Water	Wheel	* 15.70 25.25	46.00	1,571	42¾	43.96	.96	....	†2.50	055	.06	.003 +
6	Mrs. J. W. Harrington	3	E. Motor	8.78	35.00	1,852	50½	92.45	2.64	Flat	84.00	2.40	.91	.10 +
7	C. Hendrickson	3	E. Motor	* 22.12 39.37	15.73	1,596	43½	34.32	2.18	Meter	84.00	5.34—	2.45	.08 +
8	Kimball & Son	5	E. Motor	27.23	27.66	277	7½ +	15.23	.55	Flat	100.00	3.62	6.57	.24 +
9	J. H. Parsons	4	Gas Eng.	17.25	25.00	351	9½ +	11.29	.45	Gas and oil.	33.43	1.34	2.96	.17 +
10	Payette Heights	2-75	E. Motor	131.16	600.00	3,478	95 +	1,482.46	2.47	Flat	3,187.50	5.31 +	2.15	.01 3/5 +
11	Pence & Kent	5	E. Motor	15.42	70.00	3,155	86 +	196.37	2.81	Flat	140.00	2.00	.71 +	.04½ +
12	E. E. Record	5	E. Motor	13.83	32.53	566	15½ +	40.63	1.25	Meter	80.00	2.46 +	1.97 +	.14 +
13	Riverside	40	E. Motor	19.68	500.00	3,403	92 3/5 +	1,257.60	2.51	Flat	1,000.00	2.00	.80 +	.04 +
14	L. H. Rumbaugh	5	E. Motor	* 11.74 17.45	23.86	2,141	58⅓ +	102.40	4.29	Flat	140.00	5.87	1.37	.09½ +
15	Schrader & Kyle	10	E. Motor	28.43	135.00	2,902	79 +	330.26	2.45	Flat	280.00	2.07	.85	.03 +
16	P. E. Short	2	E. Motor	* 6.07 7.30	20.06	480	13 +	12.28	.61	Flat	56.00	2.79	4.56	.68 +
17	G. W. Shurtleff	12	Gas Eng.	* 21.42 58.93	22.01	287	7 4/5	29.10	1.32	Gas and oil.	167.60	....	5.76	.14⅓—
18	J. W. Stoneman	18	Gas Eng.	67.23	35.98	232	6⅓	18.23	.40	Gas and oil.	96.40	2 68	5.29	.08 +

* Lifts averaged. † $36.00 expended for repairs.

The investigation as a whole showed up many interesting factors in connection with the pumping of water for irrigation purposes, principal among which are:

(1) That greater care should be used in the designing and installation of the small plants so as to reduce the friction of shafts and belts, of water in the pipes and all other losses to a minimum. Pumps direct connected on the same shaft with the motor and bolted to the same base are recommended. Suction pipes should be as short as possible and intakes should be screened to keep out all trash. Discharge pipes should contain as few sharp turns as possible, and there should be no 90 degree angles in them. These pipes should also be of a rather large bore or diameter so as to reduce friction losses as much as possible. The inefficiency of, and abnormal amounts of power consumed by the small "stock" pumps that might or might not have been running at the speed or pumping against the head for which they were best designed, was strikingly emphasized. The design of hydraulic machinery, and particularly centrifugal pumps, is a complicated problem at the best, and the investigation as a whole, as will be seen from some of the abnormal pumping costs, seems to emphasize the desirability of having all but the smaller sizes of installation designed and installed by a hydraulic engineer who is known to be competent.

(2) It is not possible, generally speaking, to operate pumping plants continuously. It should, however, be possible to operate a small, well designed plant at least 75 per cent of the time during the season. With the present power rates it is not economical for the consumer to own a plant any larger than would be required to pump the necessary water by operating three-fourths of the time.

(3) The charges for power that were paid by the consumers for the small or average size pumping plants for a five months' season was $28.00 per horse-power for plants up to 20 horse-power; $26.00 per horse-power for plants from 20 to 40 horse-power; $25.00 per horse-power for plants from 40 to 75 horse-power. The above was the flat rate charge per horse-power. The other class of contract was a combination of the meter and flat rate as follows: $10.00 per horse-power service charge for a five months' season, plus two cents (2c) per kilowatt hour

for all current consumed with a $20.00 per horse-power minimum charge for the season.

The results of the investigation seem to indicate that the development of new lands in Idaho at the present time will not withstand the charges necessary when water is raised over 150 feet, and not over 100 feet would be recommended in many cases except with the larger installations where a much higher efficiency can be secured. The above seems true in most cases for lifts above 100 feet, for the annual maintenance, which includes (a) expense of attendants, including ditch riders; (b) repairs and general depreciation of plant; (c) interest on original cost; (d) charges for power, lubricating oil, etc., will be too excessive for the development of raw land except in exceptional cases. Old bearing orchards, vineyards and other highly remunerative crops will necessarily withstand greater power charges and consequent greater lifts than the development of raw land. It must be borne in mind that the man under the pumping plant with his high annual maintenance charge must in almost all cases compete with his neighbor under a gravity canal with a consequent lesser charge for annual maintenance.

The results of the investigation as a whole were quite satisfactory, but owing to the flat rate power charges and the $20.00 minimum clause in the meter rate contracts, it was found that there was no more incentive to save water than under some of the gravity canals. Some of the users were particularly wasteful of their water. This was very disappointing, but in all probability added time will give both the farmers and the power company experience that will tend to better the conditions that now exist. The major factor brought out by the investigation was the desirability of better designed and installed equipment. This will be imperative in order to make a permanent success of irrigation pumping.

Subsequent mechanical efficiency tests showed that the over all efficiencies of the plants in the Payette district ranged from less than 25 per cent to as much as 75 per cent. The majority of the plants included in the 1913 investigation above outlined were developing efficiencies of less than 40 to 45 per cent, showing that the farmers were paying nearly twice as much power charges as should have been necessary for the amount of water pumped. The

fault, however, was invariably in the poor design and faulty installation of the plants, rather than with the rate paid for power. The farmer must be made to realize that the best designed plant of the best possible construction is by far the cheapest in the end, though the initial cost may be 50 per cent greater than some plants might be installed for.

AMOUNT OF WASTE OR UNIRRIGATED LAND IN A TYPICAL PROJECT.

The total amount of water required by any project, as has been outlined previously in this report, depends upon at least four factors: (1) the Duty of Water at the land; (2) the amount of transmission loss between the point of diversion and the land to be irrigated; (3) the amount of loss from reservoirs; and (4) the proportion of a project that is ultimately irrigated. The above factors must all be given serious consideration when designing any irrigation project, and as far as all practical purposes are concerned, are of equal importance, for to err or miscalculate in regard to any one of them might in some cases be the cause of the failure of the project.

The fourth factor, the proportion of a project that is ultimately irrigated, is considered to be fully as vital and important as any of the others which have a bearing upon the amount of water required for a project, for it would unquestionably be impossible to design any project properly and economically without a knowledge of this factor, even though all of the other factors involved were accurately known. So far as the individual user is concerned, it may be found that the irrigation company will be required to deliver him water on the basis of the number of acres actually owned and upon which he pays maintenance without regard to how much of his land is devoted to roads and waste or other uncultivated area. Yet so far as a project as a whole is concerned, it seems quite evident that the total amount of waste and unirrigated land in the project will always be a dominant factor, for even though the individual is delivered water on a basis of the area actually owned, water will not be used on the waste places, and the water for the balance of the project will be materially increased thereby.

It has been roughly estimated by many engineers in the past, there having been no accurate data in regard to the

subject, that 20 per cent of a normal project would always be unirrigated from a variety of causes. The author has always believed this estimate to be too high for Idaho projects, for wherever large bodies of high land or rough, rocky land have existed they have been eliminated from the project at the outset. It has not seemed possible that the ordinary waste or unirrigated area, consisting of county roads, railroad rights of way, ditch rights of way, fence rows, corrals, stack yards, small high spots and other wastes of all kinds has amounted in any one year on a well developed project to as much as 20 per cent of the total area for which water rights were provided. Realizing the extreme importance of this factor and the utter lack of dependable data in regard to it, it was decided some two years ago that this factor should be determined for Idaho conditions. It was decided that the determination should be made by means of an actual survey of typical irrigated land, in contiguous bodies located in at least two different typical Idaho irrigation projects.

After considering several projects and looking over a large amount of land, two localities were selected as being typical of Idaho's irrigation projects. One of these was in the Boise Valley in the vicinity of Meridian, where land had been farmed for fifteen or more years, and the other was in the heart of the South Side Twin Falls Project, in the vicinity of and surrounding the town of Kimberly, five miles east of Twin Falls. Twenty sections were surveyed in a contiguous body lying immediately north of and adjacent to the town of Meridian, and skirting the Boise Valley bottom lands on the south. The land surveyed was all bench land and was typical in every respect of the better class of irrigated land in the Boise Valley. The other area surveyed consisted of six sections entirely surrounding, but one-fourth of a mile removed, from the Kimberly townsite. This land was typical in every respect of the better class of irrigated land on the South Side Twin Falls Project. Land immediately adjoining the towns was not included in the investigation, for it was divided into such small holdings that it was considered not typical of a project as a whole. Sections were frequently encountered during the survey that seemed to vary somewhat from the typical on account of too much or too little waste land, but as the specific area to be surveyed had been predetermined as typical these areas were always included along with the rest so as to

eliminate the personal equation of the men who did the actual field work.

These surveys were made with the transit and chain. The notes were platted on detail paper to a scale of 200 feet to the inch and the areas were determined with a polar planimeter. A reasonable amount of care was always used, and while it is known that the areas included in the table are not exactly accurate, there is no doubt but that they are accurate enough for all practical purposes.

The total areas devoted to each of the various irrigated crops and the total areas devoted to the various non-irrigated areas were segregated and are shown in the table which follows. As most of the surveys were made during the fall and spring, or non-irrigation season, it has not been possible to determine the exact amount of land that was unused or fallow for a variety of reasons, and there is no column set aside for this class of land in the table. The field men who made the survey insist that there was none, and that whatever fallow land that existed in the entire area was still devoted to sage brush that could and would be cultivated and irrigated at no distant date.

It is believed that the total area surveyed, consisting of 16,065.21 acres, is large enough so that a dependable estimate for similar projects may be based upon it, for the total area considered is in itself as large as some irrigation projects, and is one-quarter or one-half as large as the majority of them in the West today. It is realized that there is always a small amount of fallow land in any project that may be uncultivated for a year or two for a variety of reasons, such as sickness or death of the owner, failure to find a renter, trouble over water rights, or ditch rights of way, or the breaking of ditches. While it is realized that such fallow land will always exist in all projects, it is believed that the per cent devoted to it will necessarily be very small in a typical highly-developed South Idaho project, and that it will never exceed over 1 or 2 per cent of the total area, where the project is well developed, which intensive development must take place if the project is to be a success. For those who have use for the data contained in the table, it is suggested that not over 1 to 2½ per cent should be added for fallow land to the waste or non-irrigated acreage shown. The addition of a percentage for fallow land to the percentage shown in the table should give the total waste or non-irrigated area of the project.

Space will not permit of even a brief description of each of the sections that have been surveyed, and the readers must assume that they consist of typical, well irrigated land, planted to diversified crops. A study of the detailed table, however, should furnish considerable information in regard to each section. The 20 sections in the vicinity of Meridian consisted of holdings of various sizes, these holdings ranging from 4 to 19 different farms per section. The average for the entire area surveyed was 10.65 farms per section.

Acreages and Percentages of Irrigated and Waste Land Included in Twenty-six Sections of Typical Idaho Irrigated Lands.

Number	Section	Irrigated acreage						Non-irrigated or waste acreage					
		Hay and pasture		Grain, orchard, root crops and misc.		Total irrigated		Corrals, barn & stack yds, fence rows, bldg. sites and highland		Sloughs, cre'ks, canals county roads, R. R. rights of way and misc.		Total waste	
		Area	Per cent	Area	Per cent	Area	Per cent	Area	Per cent	Area	Per cent	Area	Per cent
1	28 T. 10 S., R. 18 E., B. M.	189.1	39.22	251.0	52.07	440.1	91.29	12.5	2.59	29.5	6.12	42.0	8.71
2	27 T. 10 S., R. 18 E., B. M.	160.0	24.79	401.8	62.29	561.8	87.08	16.1	2.49	67.3	10.43	83.4	12.92
3	22 T. 10 S., R. 18 E., B. M.	300.3	46.67	278.7	43.31	579.0	89.98	13.7	2.13	50.8	7.89	64.5	10.02
4	21 T. 10 S., R. 18 E., B. M.	95.7	17.51	403.6	73.90	499.3	91.41	10.0	1.83	36.9	6.76	46.9	8.59
5	29 T. 10 S., R. 18 E., B. M.	94.9	19.60	343.7	71.16	438.6	90.76	18.2	3.80	26.2	5.44	44.4	9.24
6	20 T. 10 S., R. 18 E., B. M.	139.6	29.00	290.6	60.11	430.2	89.11	16.4	3.41	35.8	7.48	52.2	10.89
7	28 T. 4 N., R. 1 E., B. M.	348.1	53.97	246.9	38.28	595.0	92.25	16.3	2.52	33.7	5.23	50.0	7.75
8	29 T. 4 N., R. 1 E., B. M.	302.4	46.70	291.9	45.08	594.3	91.78	15.3	2.36	37.9	5.86	53.2	8.22
9	32 T. 4 N., R. 1 E., B. M.	357.9	55.37	242.3	37.47	600.2	92.84	16.1	2.49	30.2	4.67	46.3	7.16
10	33 T. 4 N., R. 1 E., B. M.	115.9	17.76	478.6	74.13	594.5	91.89	15.3	2.36	37.2	5.75	52.5	8.11
11	31 T. 4 N., R 1 E., B. M.	341.8	55.61	242.0	39.67	583.8	94.98	11.6	1.89	19.2	3.13	30.8	5.02
12	4 T. 3 N., R. 1 E., B. M.	364.5	57.06	221.1	34.59	585.6	91.65	19.4	3.04	33.9	5.30	53.3	8.34
13	5 T. 3 N., R. 1 E., B. M.	323.1	50.77	267.5	42.01	590.6	92.78	15.9	2.51	30.0	4.76	45.9	7.27
14	6 T. 3 N., R. 1 E., B. M.	262.7	43.29	297.7	49.00	560.4	92.29	9.2	1.72	37.6	5.99	46.8	7.71
15	1 T. 3 N., R. 1 W., B. M.	351.8	53.56	251.2	38.25	603.0	91.81	16.2	2.47	37.6	5.72	53.8	8.19
16	2 T. 3 N., R. 1 W., B. M.	253.4	39.65	331.6	51.86	585.0	91.51	15.7	2.46	38.5	6.02	54.2	8.48
17	10 T. 3 N., R. 1 W., B. M.	226.7	35.12	348.5	53.98	575.2	89.10	11.6	1.79	58.7	9.11	70.3	10.90
18	11 T. 3 N., R. 1 W., B. M.	237.7	36.96	340.0	52.87	577.7	89.83	8.1	1.27	57.3	8.90	65.4	10.17
19	25 T. 4 N., R. 1 W., B. M.	412.3	62.18	201.9	32.77	614.2	94.95	10.8	1.64	21.9	3.41	32.7	5.05
20	26 T. 4 N., R. 1 W., B. M.	251.4	39.55	339.6	53.44	591.0	92.99	19.0	3.00	25.5	4.01	44.5	7.01
21	27 T. 4 N., R. 1 W., B. M.	293.3	46.00	309.9	48.59	603.2	94.59	6.7	1.05	27.8	4.36	34.5	5.41
22	28 T. 4 N., R. 1 W., B. M.	281.0	44.39	318.0	50.22	599.0	94.61	8.0	1.26	26.1	4.13	34.1	5.39
23	33 T. 4 N., R. 1 W., B. M.	390.6	61.54	197.9	31.20	588.5	92.74	9.9	1.56	36.2	5.70	46.1	7.26
24	34 T. 4 N., R. 1 W., B. M.	204.2	31.86	388.7	60.64	592.9	92.50	11.9	1.86	36.2	5.64	48.1	7.50
25	35 T. 4 N., R. 1 W., B. M.	318.4	49.93	258.9	40.59	577.3	90.52	16.0	2.51	44.4	6.97	60.4	9.48
26	36 T. 4 N., R. 1 W., B. M.	347.0	53.52	263.3	40.62	610.3	94.14	14.2	2.19	23.8	3.67	38.0	5.86
	Total	6963.8	.....	7806.9	.....	14770.7	.....	354.1	.....	940.2	.....	1294.3	.....
	Percentage	....	43.34	....	48.60	....	91.94	....	2.20	....	5.86	....	8.06

Space will not permit of including carefully prepared maps of a sufficiently large scale to show up the individual differences that existed between the sections surveyed, nor of a table of sufficient size to show the acreages of all classes of crop that existed in each individual section. The above table gives the results secured from the survey in a rather condensed form, which, it is believed, will be detailed enough for all practical purposes. In working up the data, each class of crop or class of waste land was totaled separately. Of the area surveyed, which consisted of 16,065.21 acres, 4,417.22 acres, or 27.5 per cent, were devoted to hay; grain, 4,327.56 acres, or 26.94 per cent; pasture, 2,447.58 acres, or 15.24 per cent; potatoes, 137.19 acres, or 0.85 per cent; orchard, 2,360.4 acres, or 14.69 per cent; vineyard, 2.76 acres, or 0.02 per cent; corn, 17.26 acres, or 0.11 per cent; garden, 105.58 acres, or 0.66 per cent; sugar beets, 155.25 acres, or 0.97 per cent; clover, 94.72 acres, or 0.59 per cent; beans, 25.14 acres, or 0.16 per cent; berries, 3.01 acres, or 0.02 per cent; peas, 198.69 acres, or 1.23 per cent; sage brush which will be irrigated, 199.62 acres, or 1.24 per cent; home grounds, 5.03 acres, or 0.03 per cent; miscellaneous irrigated crops, 273.68 acres, or 1.7 per cent, making a total irrigated acreage of 14,770.69 acres, or 91.94 per cent. The waste or non-irrigated acreage consisted of corrals, 99.85 acres, or 0.62 per cent; barn and stack yards, 24.78 acres, or 0.16 per cent; fence rows, 87.49 acres, or 0.55 per cent; sloughs, 44.15 acres, or 0.28 per cent; creeks, 97.33 acres, or 0.61 per cent; canal and ditch rights of way, 229.14 acres, or 1.43 per cent; county and private road rights of way, 351.19 acres, or 2.18 per cent; railroad rights of way, 93.38 acres, or 0.58 per cent; coulees, 93.10 acres, or 0.57 per cent; building sites, 139.35 acres, or 0.86 per cent; high land, 2.67 acres, or 0.02 per cent; miscellaneous non-irrigated areas, 32.09 acres, or 0.2 per cent, making a total non-irrigated acreage of 1,294.52 acres, or 8.06 per cent, the total area surveyed consisting of 16,065.21 acres. The reader will bear in mind when consulting this table that all lands to which water was not applied, except uncleared land which could and will be irrigated, is listed under waste land. Considering the investigation as a whole from the detailed data which are given in the table, it would seem as though none of Idaho's normal projects would ultimately have

over 10 per cent of waste or non-irrigated land contained in them, provided the size of the projects is based on the number of acres sold and for which maintenance is annually paid. The data therefore seem to prove conclusively that where it is desired to irrigate 100,000 acres, an ample and dependable water supply for at least 90,000 instead of only 80,000 should be secured.

SEEPAGE INVESTIGATION.

There has always been a serious lack of dependable data concerning the transmission losses of Idaho canals. It seems to have been customary when designing Idaho projects to allow for a loss of one per cent per mile, based upon the amount carried at the upper end of each one-mile section. This estimate has been made rather arbitrarily and without much data to back it up, but on the whole has given fairly good results when normal soil conditions have been encountered. Realizing that irrigation water was becoming more valuable each year and that projects were being continually based on narrower margins it became apparent that the transmission loss to which a project would be subject was an extremely vital factor. It was felt that this factor was fully as important as the Duty of Water at the land or the percentage of the project that is ultimately irrigated, and it was decided to broaden the Duty of Water investigation by determining the seepage losses on a sufficient number of canals so that a stable basis for further estimates of these losses might be secured. It was known that the type of material through which a canal was built had an important bearing on the subject, and it was hoped through investigation to determine an average loss for the different soil types and thus establish a safe basis to work from in the future. An investigation of the subject was initiated in the spring of 1912 and carried on uninterruptedly throughout that and the following irrigation season, during which time seepage losses were determined on 118 sections of different canals with a total length of nearly 300 miles.

Canal Losses.

Canals are subject to three different kinds of transmission losses. These are leakage, evaporation and seepage. The losses from leakage are usually caused by cheap and

improper construction or wornout structures, and should be practically negligible with an efficient, well-designed and carefully maintained canal.

The evaporation losses from canals are usually so small as to be almost negligible. Careful mathematical determinations of this factor show that the evaporation losses from typical Idaho canals usually amount to not over one per cent of the total loss to which water is subject in transmitting it from the point of diversion to the point of application to the land, 99 per cent is usually due to seepage and only 1 per cent to evaporation from the water surface.

That the above is true may be roughly determined very easily by any one. The evaporation from a free water surface in evaporation tanks installed for the purpose at different points well scattered throughout irrigated South Idaho averages about 1.5 inches per week throughout the irrigation season, and has never been known either at Twin Falls, Caldwell or Gooding, to exceed over 2.3 inches in any one week. A typical canal with a water surface 1 rod wide would have 2 acres of surface exposed per mile. A normal capacity for a canal of this width would be at least 125 cubic feet per second. A normal loss for this canal would be 1 per cent per mile, or 1.25 second feet, which would be equivalent to 2.5 acre feet per day, or 17.5 acre feet per week, whereas the evaporation loss from this same canal with its exposed surface of 2 acres could not average over 3 acre inches, or one-quarter of an acre foot per week. This evaporation loss, which is the highest that could possibly take place from the surface of the cool water in the canal, would thus in the above case amount to only one-seventieth of the total amount lost by the canal from both seepage and evaporation. The striking comparison that exists between the evaporation and the seepage losses that are experienced from typical canals was well brought out in the last biennial report of the Idaho State Engineer's office, and the above discussion is included here to further emphasize the very small losses that ordinary canals experience through evaporation from their exposed surface. Since the losses from leakage and evaporation are so insignificant in comparison to those experienced from seepage the losses in this report will all be classed as seepage losses.

Units Used to Express Seepage Losses.

It has long been customary to express the seepage losses as per cent of the total flow lost per mile of canal, based on the flow at the upper end of each 1-mile section. This, however, is a very misleading and unsatisfactory method of expressing these losses, for they are not only largely independent of the amount of water flowing in the canal, but the loss when expressed in per cent per mile shows an abnormal increase in canals of small capacity.* It will be seen that a canal carrying only a small per cent of its capacity will lose an abnormally large per cent per mile, while if the losses are expressed as so much per unit of wetted area they are bound to be less misleading and will compare favorably with the losses experienced when the canal is full.

While there are many factors which influence and affect the amount of loss by seepage, the loss is unquestionably a function of the wetted perimeter and must be expressed in terms of quantity lost per unit of wetted area if comparable results between different canals are to be obtained. For this reason all losses in this report are expressed as "cubic feet lost per twenty-four hours for each square foot of wetted area in the canal bed" as well as in "per cent of loss per mile."

Method of Measurement.

Ditches or laterals carrying three second feet or less were measured with Cippoletti weirs which were carefully installed at the upper and lower ends of each section. The head on these weirs was read to the nearest .001 of a foot with small, inexpensive hook gages which were designed especially for the purpose. All of the larger laterals and canals were measured by current meters. Where convenient bridges could be found from which to make measurements these were used, but wading measurements were found necessary on some of the broad shallow canals carrying only a small per cent of their capacity. The measurements of the South Side Twin Falls Main and High Line Canals were made from a boat especially fitted up for the purpose. This boat was attached to cables stretched across the canal in much the same manner as a small ferry

*See Bulletin No. 126, U. S. Department of Agriculture, by Samuel Fortier.

boat. The North Side Twin Falls, the second largest canal included in the investigation, was rated from a car suspended on cables which were installed above and across the canal at appropriate places. The meters used in the work were the standard Gurley Price weight meters. These meters were all rated at the beginning of the 1912 season, one new one having been rated by the Bureau of Standards at Washington, D. C., and the others at the rating station of Irrigation Investigations at Berkeley, California. The 1912 rating was used for all 1912 determinations, and all meters were again rated at the rating station of Irrigation Investigations at Berkeley, California, at the close of the season of 1913. Most of them showed a remarkable agreement with the 1912 rating, only one being off far enough to vitiate the results obtained. The 1913 measurements made with this meter were changed in accordance with the rating curve made up for it in the fall of 1913.

The .2, .6 and .8 or three-point method of measurement was used in all cases where the water exceeded a depth of one foot, and either the .6 or integration method with shallower ditches. In computing the discharges the following formula was used:

$$\frac{(\text{Vel. at }.2)+(2x\text{ Vel. at }.6)+(\text{Vel. at }.8)}{4} \text{ equals ``av'ge velocity''}$$

The fluctuations of gage height or intermittent rise and fall of the water has been the most troublesome factor with which hydrographers have had to contend in the making of seepage measurements in the past, and it was decided to eliminate this factor as nearly as possible so that it could have no appreciable effect on the results secured in this investigation. It is believed that this was thoroughly accomplished, and as the method used was more or less original and has not been seen in print elsewhere, it will be given here with the hope that it might be of assistance to other engineers and hydrographers who may be called upon to make accurate determinations of the seepage losses from canals.

The canals included in the investigation, and upon which seepage losses were to be determined, were looked over and examined quite thoroughly before any measurements were made. Rating stations were picked out and established at the head of all diversions and at intervals

of as near two miles apart in the main canal as sections suitable for the purpose could be found. Gages which could be read to the nearest .02 of a foot were then installed at each station, after which the canal was rated at each station by at least two hydrographers, each with a different meter, in order to avoid not only error in computation, but to eliminate the personal equation of the man, and any slight discrepancies in the meters. Rating curves were then plotted for each section measured using the bottom of the canal as the zero point on the curve and the point at which water stood when the ratings were made for the only other point which was determined on each curve. The water level in the canal was maintained throughout and for some time after the measurement as nearly constant as it could be, there being usually less than .05 of a foot fluctuation in the water level during the period covered by the investigation. After all of the stations selected had been rated by the two men, measurements were discontinued for a day and floats consisting of tightly corked bottles or tin cans were dropped into the main canal at the upper gage and allowed to float downward with the current. These floats were started at daylight, a man proceeding down with them and reading each gage in the main canal and in all of the diversions at the time that the floats passed the gage in question. More floats and another man followed the first ones at 2 or 3 hour intervals throughout the entire day and the discharge at and consequent seepage losses between each two different points was calculated from the discharge based on the rating curves and gage heights at the time that the floats passed the different stations.

Determinations by the above method compare discharges of practically the same flow or wave of water at the time it passed different points, and is believed to be far more accurate than any simultaneous measurements. While the floats did not necessarily proceed down the canals at exactly the same rate as the average velocity of the ditch, and while the rating curves, each of which were based on but two points, may not have been absolutely accurate, the canals were held as uniform as possible, and as there was but slight fluctuation in any case between the time of the original rating and the time the floats passed the gages it is believed that the discharges secured from the curves are

quite accurate and that the results, secured as above outlined, have eliminated personal equations of men, individual characteristics of meters, and slight fluctuations of canals and are more accurate on the whole and better than any other method that has yet been devised. The table which follows the descriptions given below gives the average seepage loss for a 12 or 14 hour period of the different sections of each canal that have been investigated. It is regretted that space will permit of only a very brief description of the canals included in the investigation. They are all more or less typical of the ordinary canals in use throughout the West and it is hoped that the following brief description will furnish sufficient data to give a fairly accurate idea of the different sections included in the investigation.

The numbers of the following paragraphs correspond with the numbers of the different sections in the seepage table, and are arranged in practically the same order.

1 to 21 inclusive. Typical small farm laterals located on the South Side Twin Falls Project, Salmon River Project and the Ridenbaugh Canal in the Boise Valley. The majority of the soils through which these laterals were constructed consisted of the medium clay loam or lava ash common to South Idaho. The majority of these soils were underlaid with calcareous hard pan at depths ranging from one and one-half to four feet. Some of these laterals had rather swift velocities, erosion having taken place down to the hard pan.

22. This section was located five and one-half miles southwest of Rigby in the Upper Snake River Valley and was constructed through a gravelly sandy loam soil.

23. A typical farm lateral on the South Side Twin Falls Project.

24. A lateral of the Salmon River Project near Amsterdam. The abnormal amount of seepage from this lateral was caused by the shallow soil through which it was constructed, there having been a large amount of shale incorporated into its banks.

25 to 28 inclusive. Typical laterals on the South Side Twin Falls and Salmon River Projects.

29. Typical lateral on the Portneuf Marsh Valley Project near Downey.

30 to 33 inclusive. Typical laterals of the Oakley Project.

34 and 35. Laterals near Rigby; constructed through very gravelly soil.

36 and 37. Laterals near Hollister. Clay loam soil.

38 to 40 inclusive. Laterals of the Oakley Project.

41. Lateral near Rigby; constructed through very gravelly soil.

42. Typical lateral, Salmon River Project.

43 to 45 inclusive. Typical laterals, Oakley Project.

46. Lateral of the Burgess Canal near Rigby; constructed through a medium gravelly soil.

47. Typical lateral of Portneuf Marsh Valley Project near Downey.

48 to 51 inclusive. Typical laterals of North Side Twin Falls, South Side Twin Falls and Oakley Projects. Section 50 showed a gain occasioned by porous irrigated land above the canal.

52. Lateral of Burgess Canal near Rigby; constructed through gravelly soil.

53. Typical lateral of South Side Twin Falls Project.

54 and 55. Main Canal of Murphy Land & Irrigation Co., constructed through medium clay loam soil, section 55 containing a few somewhat gravelly side hill sections.

56. Extension of East Side Main Canal, Oakley Project; constructed through heavy clay loam soil slightly mixed with sand; heavy grade with consequent swift velocity.

57. Lateral of Twin Falls North Side Project near Wendell.

58. Lateral C, Portneuf Marsh Valley Irrigation Project, 2 miles north of Downey.

59. Portion of Main Canal, Twin Falls Salmon River Project.

60. Portion of Vance Canal four and one-half miles southwest of Rigby. Soil very gravelly.

61. Section of Main Canal of the Twin Falls Salmon River Project, commonly known as "Main 2" Canal, carrying only a small per cent of its capacity.

62 to 64 inclusive. Parts of Main Canal, Portneuf Marsh Valley Project.

65. West Main Canal, Oakley Project. First season of use; was constructed around a very gravelly hillside.

Lower bank showed much gravel but contained sufficient percentage of clay to render it comparatively impervious.

66 and 68. Main Canal, Portneuf Marsh Valley Project.

67. Lateral 21 of Salmon River Project. Rather shallow clay loam soil with banks solid and compact.

69. Typical lateral of South Side Twin Falls Project.

70. Portion of Main Canal of Salmon River Project near Hollister, carrying only a small per cent of its capacity.

71. West Main Canal, Oakley Project. Canal was constructed through a gravelly side hill formation which had a sufficient amount of clay mixed with it to render it comparatively impervious.

72 and 74. Typical laterals of South Side Twin Falls Project.

73. Lateral A of Salmon River Project, carrying only a small per cent of its capacity.

75, 83, 87, 89, 98, and 100. Main Canal of Pioneer Irrigation District in the Boise Valley. Section 75 of this canal was located between Caldwell and Nampa and traversed a territory where ground water was very close to the surface. The gain in this section was due to the proximity of the ground water. The remainder of this canal was fairly typical of Idaho canals, having been constructed almost entirely through a clay loam soil of a medium nature.

76 and 77. East Side Main Canal, Oakley Project.

78 and 79. Portions of Main Canal, Twin Falls Salmon River Project.

80. Randall Canal near Rigby; constructed through gravelly soil.

81 and 82. Main Canal of Deitrich segregation, Idaho Irrigation Company's Project near Richfield. Section 81 was constructed in the main through clay loam soil but contained several rock cuts.

84. Consisted of the entire length of Perrine Coulee, the well-known lateral on the South Side Twin Falls Project. This coulee was measured during the month of July, 1913, at the height of the irrigation season. Measurement of this coulee was made at this time to determine whether or not well defined coulees picked up enough waste water from the adjacent farms to more than offset

their seepage losses. Extreme care was used in the measurement of this coulee and it was found that the waste water which was picked up hardly equaled or offset the loss in the coulee by seepage, the net loss being .1 of one per cent per mile. The section of the coulee was so irregular that there was no attempt made to base the seepage losses on the amount of wetted area in the coulee.

85 and 86. Portions of Main Canal, Twin Falls Salmon River Project. Section 86, first section below the check basin, listed as 99 and 101.

88 and 90 to 95 inclusive. Farmers' Co-operative Canal in the Payette Valley near Emmett. It had been thought by some that this canal had abnormal losses and that the seepage conditions in the valley were largely due to the losses from this canal. The losses from the canal, as will be seen from the table, were rather low. One section, where ground water was near the surface in the surrounding soil, showd a gain. The measurements as a whole clearly indicate that the seepage conditions in the Payette Valley are not caused by the seepage losses from this canal. Soil, a clay loam and sandy loam.

99 and 101. The check basin in the Main Canal of the Salmon River Project. These two sections represent measurements of this check basin during the different years. Results represented by No. 99 were secured during the season of 1912, and those represented by No. 101 were secured during July of 1913. This check basin is simply an enlargement of the canal or a pot hole which is used as part of the canal section to eliminate the necessity of constructing a canal around it. The check basin covers about 62 acres when full. The soil in the bottom of the basin is a clay loam varying in depth from one to two feet, underlaid by lava rock. The measurements clearly indicate that it would be wise to construct a canal around this depression.

102 to 106 inclusive. Include the High Line Canal of the South Side Twin Falls Project from the point where it leaves the Main Canal to Cottonwood Flume south of Kimberly. This canal shows a gain in two different sections. Section No. 102 is that portion which crosses McMullin Creek, and section 104 is that portion which crosses Rock Creek, there being porous irrigated land lying above each

one of these sections. The gain clearly indicates that the canal in these sections is picking up from sub-surface sources some of the underground water from the porous irrigated land above.

107 to 112 inclusive. Represents results secured from different sections of the Main Canal of the North Side Twin Falls Project from Milner to Jerome Reservoir. The Upper end of Section 112 is located at the Milner Dam, and the lower end of Section 107 includes part of Jerome Reservoir. Part of Section 112 is lined with concrete. Section 111 includes Wilson Lake Reservoir.

113 to 118 inclusive. Includes the Main Canal of the Twin Falls South Side Project from Milner to the point approximately 25 miles below where the Main Canal divides into the High and Low Line Canals. Section 116 includes Dry Creek Reservoir only. This reservoir is formed where the main canal crosses Dry Creek, where the canal simply consists of a lower bank, the water backing up Dry Creek far enough so that it forms a lake covering 965 acres. The embankment is approximately one mile long and 35 feet high. No. 118 is that portion of the canal extending from the wagon bridge near Milner and immediately below the dam to a point 3.35 miles below. There are several rock cuts throughout this section, it being the only section where an abnormal loss occurred. The losses in all other sections were practically normal, yet the canal lost over 500 cubic feet per second throughout the section observed, which was less than 25 miles in length. When considered from the standpoint of the total amount of loss alone, leaving out of consideration the percentage, this loss is thoroughly enormous.

The South Side Twin Falls Canal is constructed principally through a clay loam soil of a rather impervious nature and was running very full of water at the time of the investigation.

Table Showing Transmission Losses of Canals—Season of 1912 and 1913.

Number	Location	Date	Year	Av. depth of water—feet	Av. width of water sur—ft	Area wetted cross section —square feet	Wetted perimeter	Hydraulic radius	Mean veloc'ty ft. per second	Discharge at upper end of section—second feet	Discharge at lower end of section—second feet	Total loss in section—second feet	Length of section observed—miles	Loss per mile—second feet	Loss in cu. ft. per sq. ft. wetted area per 24 hours	Per cent loss per mile	Remarks
1	Farm Lateral	9-10	1912	.13	.9	.117	1.03	.113	.55	.073	.056	.017	.490	.035	.564	48.0	
2	Farm Lateral	6-20	1912	.16	1.0	.164	1.17	.140	.84	.145	.130	.015	.399	.038	.549	26.9	
3	Farm Lateral	9-14	1912	.14	1.4	.190	1.51	.126	.97	.205	.165	.040	.700	.058	.625	28.3	
4	Farm Lateral	6-27	1912	.21	1.5	.318	1.69	.188	.74	.277	.194	.083	.682	.121	1.170	43.6	
5	Farm Lateral	6-26	1912	.28	1.5	.415	1.78	.233	.78	.364	.283	.081	.379	.214	1.971	58.8	
6	Farm Lateral	9-11	1912	.32	1.5	.476	1.87	.255	1.04	.532	.464	.068	.714	.095	.828	17.8	
7	Farm Lateral	9-13	1912	.28	1.0	.280	1.35	.208	1.82	.545	.475	.070	.740	.095	1.146	17.4	
8	Farm Lateral	6-19	1912	.15	1.5	.224	1.62	.138	2.49	.575	.542	.033	.378	.087	.880	15.2	
9	Farm Lateral	5-27	1912	.25	1.8	.450	2.30	.196	1.49	.685	.655	.030	.469	.063	.449	9.1	
10	Farm Lateral	9-13	1912	.22	1.9	.427	2.11	.202	1.73	.802	.676	.126	.528	.238	1.843	29.6	
11	Farm Lateral	9-12	1912	.23	1.5	.350	1.72	.204	2.32	.837	.807	.030	.422	.071	.676	8.4	
12	**Farm Lateral**	7-2	1913	.35	1.5	.525	2.20	.238	1.51	.852	.733	.119	.435	.273	2.029	32.1	
13	Farm Lateral	9-9	1912	.28	1.3	.360	1.62	.222	2.35	.871	.826	.045	.573	.078	.788	8.9	
14	Farm Lateral	6-20	1912	.27	3.5	.958	3.72	.258	.99	.987	.919	.068	.519	.132	.677	13.3	
15	Farm Lateral	9-12	1912	.29	1.8	.524	2.11	.248	2.04	1.123	1.019	.104	.480	.216	1.677	19.2	
16	Farm Lateral	6-28	1912	.40	2.5	1.015	2.90	.349	1.16	1.219	1.123	.096	1.534	.062	.352	5.1	
17	Farm Lateral	6-21	1912	.29	2.0	.581	2.30	.253	2.19	1.276	1.265	.011	.351	.033	.233	2.5	
18	Farm Lateral	5-27	1912	.28	4.3	1.200	4.58	.262	1.03	1.282	1.196	.086	1.623	.053	.189	4.1	
19	Farm Lateral	7-2	1913	.40	1.8	.720	2.60	.276	1.87	1.406	1.288	.118	.316	.373	2.354	26.5	
20	Farm Lateral	5-26	1912	.34	3.6	1.240	3.96	.314	1.94	1.454	.892	.562	5.254	.107	.442	7.6	
21	Farm Lateral	7-1	1913	.23	3.4	.782	3.86	.202	1.81	1.481	1.347	.134	.553	.242	1.025	16.3	
22	Farm Lateral	8-26	1912	.86	3.0	2.595	4.05	.641	.67	1.910	1.545	.365	.662	.551	2.227	28.8	Gravelly.
23	Farm Lateral	9-14	1912	.34	2.4	.824	2.82	.292	2.31	2.033	1.768	.265	.945	.280	1.626	13.7	
24	Farm Lateral	7-2	1913	.45	3.0	1.350	3.90	.346	1.43	2.047	1.820	.227	.352	.645	2.705	31.5	
25	Farm Lateral	7-3	1913	.50	2.2	1.100	3.20	.343	1.84	2.067	1.972	.095	.420	.225	1.153	10.9	
26	Farm Lateral	6-18	1912	.31	3.0	.922	3.30	.280	2.34	2.184	2.135	.049	.554	.088	.433	4.0	
27	Farm Lateral	9-11	1912	.38	2.4	.914	2.83	.323	2.40	2.218	2.163	.055	.659	.084	.488	3.8	
28	Farm Lateral	6-19	1912	.42	2.5	1.064	2.98	.357	2.03	2.260	2.061	.099	.576	.173	.947	7.6	
29	Lateral P. M. Val. Pro..........	9-3	1912	.68	5.4	3.690	5.95	.620	1.02	3.840	3.665	.175	1.175	.149	.410	3.8	
30	Lat. W. 2 Oakley..............	6-25	1913	.63	7.9	4.020	8.33	.602	.86	4.540	4.100	.440	2.020	.217	.428	4.8	
31	Lat. W. 5 Oakley..............	6-27	1913	.38	6.4	2.450	6.54	.374	2.09	5.230	5.020	.210	2.650	.080	.198	1.5	
32	Lat. W. 2 Oakley..............	6-25	1913	.73	8.3	6.080	8.85	.687	.82	5.420	4.540	.880	1.980	.444	.820	8.2	
33	Lat. W. 2 Oakley..............	6-25	1913	.61	7.5	4.580	7.92	.578	1.31	6.250	5.760	.490	2.010	.243	.502	3.9	
34	Farm Lateral, Rigby...........	8-25	1912	.92	3.9	3.590	5.53	.649	1.39	5.445	4.489	.956	.498	1.921	5.687	35.2	Very Grav.
35	Farm Lateral, Rigby...........	8-25	1912	.92	4.6	4.420	5.83	.759	1.31	6.145	5.688	.457	.584	.783	2.195	12.7	Very Gravelly.

Table Showing Transmission Losses of Canals—Season of 1912 and 1913.—*Continued.*

Number	Location	Date	Year	Av. depth of water—feet	Av. width of water sur.—ft	Area wetted cross section—square feet	Wetted perimeter	Hydraulic radius	Mean veloc'ty ft. per second	Discharge at upper end of section—second feet	Discharge at lower end of section—second feet	Total loss in section—second feet	Length of section observed—miles	Loss per mile—second feet	Loss in cu. ft. per sq. ft. wetted area per 24 hours	Per cent loss per mile	Remarks
36	T. F. S. R. Lat. 13	7-7	1913	.59	7.7	4.580	7.97	.574	1.40	6.850	6.010	.84	1.984	.423	.869	6.2	
37	T. F. S. R. Lat. 13	7-6	1913	.57	8.6	4.950	8.85	.559	1.38	7.100	6.600	.500	3.944	.126	.234	1.8	
38	Lat. 28, Oakley	6-19	1913	.53	8.1	4.290	8.45	.507	1.62	7.150	6.770	0.380	1.460	0.260	.503	3.6	
39	Lat. W. 2, Oakley	6-25	1913	.63	7.3	4.620	7.82	.590	1.67	7.820	7.650	0.17	1.95	0.087	.182	1.1	
40	Lat. W. 5, Oakley	6-27	1913	.51	9.8	4.980	10.51	.473	1.57	8.070	7.530	0.540	3.010	.179	.278	2.2	
41	Lat. Burgess Canal	8-24	1912	.83	7.5	6.270	8.03	.782	1.36	8.942	8.093	.849	.520	1.631	3.325	18.2	Gravel.
42	Farm Lateral	7-8	1913	.57	8.8	5.000	9.12	.548	1.88	9.64	9.180	.460	1.968	.233	.419	2.4	
43	Lat. W. 6, Oakley	6-23	1913	.52	9.7	5.030	9.97	.504	1.97	10.020	9.850	.170	2.560	.066	.109	0.7	
44	Lat. W. 5, Oakley	6-27	1913	.55	13.3	7.340	14.10	.520	1.39	10.840	9.660	1.180	3.000	.393	.456	3.6	
45	Lat. 18, S. S. T. F. Project	8-9	1913	1.36	5.8	7.870	7.52	1.046	1.33	11.060	9.910	1.150	1.790	.642	1.397	5.8	
46	Lat. Burgess Canal	8-24	1912	1.42	7.2	10.260	9.20	1.115	1.14	12.522	10.956	1.566	1.255	1.248	2.219	9.9	Gravel.
47	Lat. P. M. Val. Pro	9-3	1912	.97	9.5	9.350	10.10	.925	1.36	13.170	12.230	.940	1.309	.714	1.157	5.4	
48	E-4-3 Lat., Oakley	6-20	1913	.80	11.9	9.560	12.75	.749	1.33	13.270	12.130	1.140	1.970	.579	.742	4.4	
49	Lateral N. S. T. F. Pro	6-6	1912	.63	11.1	7.070	12.00	1.589	1.83	14.710	11.230	3.480	2.612	1.330	1.813	9.0	
50	E-4-3 Lat., Oakley	6-20	1913	.84	9.6	8.050	10.27	.783	1.97	15.150	16.670	—1.520	1.780	—0.854	....	—5.5	Gain.
51	Lat. 16, S. S. T. F. Project	8-8	1913	.95	6.3	5.940	7.30	.813	2.79	17.050	16.180	.870	1.840	.472	1.061	2.8	
52	Lat. Burgess Canal	8-23	1912	1.35	8.6	11.600	9.88	1.175	1.54	18.536	17.185	1.351	.674	2.004	3.320	10.8	
53	Lat. 26, S. S. T. F. Project	8-7	1913	1.34	8.3	11.070	9.87	1.121	1.62	18.950	17.110	1.840	3.680	.500	.827	2.6	
54	M. Canal, M. L. & I. Co	5-23	1912	.97	10.3	10.020	11.25	.890	1.83	19.280	17.470	1.810	4.568	.396	.576	2.1	
55	M. Canal, M. L. & I. Co	5-23	1912	.98	11.2	11.000	11.73	.938	1.87	21.730	19.480	2.250	3.812	.590	.823	2.7	
56	Extension E. S. Main, Oakley	6-19	1913	.94	10.8	10.180	11.50	.885	2.04	22.100	19.600	2.500	1.830	1.366	1.944	6.2	
57	Lateral N. S. T. F. Pro	6-6	1912	.81	20.4	16.540	21.38	.774	1.30	24.050	19.050	5.000	1.936	2.583	1.977	10.7	
58	Lat. "C," P. M. Val. Pro	9-3	1912	1.37	12.2	16.760	13.20	1.270	1.41	24.150	23.040	1.110	.478	2.322	2.877	9.6	
59	T. F. S. R. Main Canal 2	7-15	1913	1.18	27.3	32.210	28.25	1.140	0.94	31.180	29.750	1.430	3.770	.380	.219	1.2	
60	Vance Canal, Rigby	8-17	1912	1.46	8.9	12.990	11.25	1.154	2.98	41.070	36.230	4.840	3.171	1.524	2.217	3.7	Gravelly.
61	T. F. S. R. Main 2	7-15	1913	.91	29.5	27.040	30.00	.901	1.49	42.980	37.980	5.000	2.210	2.260	1.233	5.3	
62	M. Canal, P. M. Val. Pro	8-31	1912	1.44	19.8	28.670	20.75	1.380	1.50	43.600	42.250	1.350	1.881	.717	.565	1.6	
63	M. Canal, P. M. Val. Pro	8-31	1912	1.58	19.7	31.060	20.75	1.500	1.43	45.500	43.600	1.900	1.746	1.088	.857	2.4	
64	M. Canal, P. M. Val. Pro	8-31	1912	1.71	19.5	33.380	20.58	1.620	1.44	50.300	45.500	4.800	3.000	1.600	1.276	3.2	
65	West Main, Oakley	6-24	1913	1.08	26.9	29.180	26.65	1.095	1.81	54.190	51.740	2.450	3.320	.738	.453	1.4	
66	M. Canal, P. M. Val. Pro	8-31	1912	1.83	21.7	39.830	22.68	1.760	1.37	59.000	50.300	8.700	4.533	1.919	1.385	3.3	
67	T. F. S. R. Lat. 21	7-13	1913	1.62	24.4	39.760	25.50	1.559	1.70	68.140	67.380	.760	3.140	.240	.155	.4	
68	M. Canal P. M. Val Pro.	8-31	1912	2.12	24.8	52.680	25.90	2.030	1.25	73.000	59.000	14.000	4.862	2.879	1.819	3.9	
69	Lat. 22 S. S. T. F. Pro	8-5	1913	2.21	12.5	27.640	15.15	1.824	2.76	77.000	75.560	1.440	1.660	0.868	0.937	1.1	
70	M. Canal, T. F. S. R. Pro	6-17	1912	1.29	45.0	58.270	46.25	1.260	1.30	78.560	72.680	5.880	2.928	2.008	.710	2.6	
71	West Main, Oakley	7-25	1913	1.44	30.0	43.460	30.52	1.424	1.79	79.500	76.600	2.900	3.320	.873	.467	1.1	

72	Culvert C, S. S. T. F. Pro.....	8-2	1913	2.09	14.8	30.850	17.37	1.776	2.92	91.460	89.260	2.200	1.570	1.401	1.318	1.5	
73	Lat. "A" T. F. S. R. Pro.....	6-15	1912	1.96	23.3	45.770	24.50	1.870	1.98	92.190	88.750	3.440	3.138	1.096	.732	1.2	
74	Culvert C, S. S. T. F. Pro.....	8-4	1913	2.85	14.3	40.630	18.40	2.208	2.31	93.900	93.760	.140	1.800	.077	.068	.1	
75	Phyllis Canal, Boise V.........	6-4	1913	3.00	15.5	46.530	20.00	2.329	2.33	106.500	111.000	—4.500	2.100	—2.143	—1.751	—2.0	Gain.
76	E. S. Main, Oakley.............	7-24	1913	1.79	20.7	37.130	21.95	1.691	2.99	112.500	109.950	2.550	2.630	.969	.721	.9	
77	E. S. Main, Oakley.............	7-24	1913	2.00	23.3	46.450	24.85	1.870	2.55	121.590	115.550	6.040	1.980	3.050	2.014	2.5	Side Hill Sec.
78	T. F. S. R. Lat. A.............	7-10	1913	2.26	23.5	53.260	25.40	2.097	2.27	126.890	114.790	12.100	3.140	3.850	2.484	3.0	
79	T. F. S. R. Main Canal........	7-12	1913	1.64	45.0	73.880	47.00	1.572	1.78	132.960	131.060	1.900	2.930	0.650	.226	0.5	
80	Randall Canal..................	8-16	1912	2.49	17.0	42.240	21.00	2.010	3.10	135.660	126.300	9.360	2.833	3.305	2.575	2.4	Gravelly.
81	Dietrich M. Canal, Richfield..	8-27	1913	2.61	38.0	99.500	39.97	2.489	1.34	139.750	128.470	11.280	4.960	2.274	.931	1.6	
82	Dietrich M. Canal, Richfield..	8-27	1913	2.56	37.0	94.770	38.62	2.454	1.50	145.500	139.750	5.750	6.260	.918	.389	.6	
83	Phyllis Canal, Boise V.........	6-4	1913	2.86	18.3	52.410	22.40	2.339	2.68	145.960	135.460	10.500	3.400	3.083	2.255	2.1	Indian Cr. Sec.
84	Perrine Coulee, T. F...........	7-19	1913	....	.....	....	......	......	....	174.650	173.340	1.310	13.000	.100	....	.1	
85	Coulee, T. F. S. R. Pro........	6-16	1912	1.72	67.5	116.050	68.25	1.700	1.65	192.370	190.070	2.300	3.809	.603	.145	.3	Coulee.
86	M. Canal, T. F. S. R. Pro......	6-16	1912	1.84	68.1	125.300	68.75	1.820	1.62	206.840	198.430	8.410	4.185	2.010	.478	1.0	
87	Phyllis C. Boise V............	5-31	1913	3.02	22.4	67.730	27.05	2.503	3.08	214.000	203.810	10.190	3.090	3.297	1.990	1.5	Mason Cr. Sec.
88	Farmers' Co. C., Emmett.....	5-21	1913	4.58	21.3	97.470	27.50	3.544	2.47	242.000	240.670	1.330	3.530	.380	.223	.2	
89	Phyllis C. Boise V............	5-30	1913	3.47	26.4	91.620	31.00	2.955	2.62	242.640	239.030	3.610	1.920	1.880	0.994	0.8	Mason Cr. Sec.
90	Farmers' Co. C., Emmett.....	5-21	1913	4.57	21.0	96.010	28.80	3.333	2.54	244.000	243.870	0.130	3.500	0.040	0.021	.1	
91	Farmers' Co. C., Emmett.....	5-17	1913	4.61	21.9	101.350	30.80	3.290	2.51	260.000	249.980	10.020	2.450	4.090	2.172	1.6	
92	Farmers' Co. C., Emmett.....	5-17	1913	4.27	24.8	106.130	33.00	3.216	2.48	265.000	261.560	3.440	2.850	1.200	.597	0.5	
93	Farmers' Co. C., Emmett.....	5-17	1913	4.15	25.8	106.970	31.30	3.417	2.54	269.990	272.000	—2.010	2.110	—0.952	—.496	—0.4	Gain.
94	Farmers' Co. C., Emmett.....	5-17	1913	4.52	25.1	113.450	32.80	3.458	2.37	272.000	265.950	6.050	2.440	2.480	1.236	0.9	
95	Farmers' Co. C., Emmett.....	5-17	1913	4.14	31.3	129.510	36.00	3.597	2.22	295.000	281.390	13.610	2.260	6.020	2.733	2.0	
96	T. F. S. R. Main Canal........	7-11	1913	2.34	68.0	159.460	70.50	2.262	1.90	307.700	299.300	8.400	3.870	2.200	.517	0.7	Coulee.
97	T. F. S. R. Main Canal........	7-11	1913	2.51	68.0	171.250	70.25	2.437	1.86	332.000	307.700	24.300	4.180	5.810	1.352	1.8	
98	Phyllis C. Boise V............	5-30	1913	3.79	32.0	121.660	36.50	3.333	2.74	333.000	333.760	—0.760	2.620	—0.290	—0.130	—0.1	Gain.
99	Check Basin, S. R. Pro.........	6-14	1912	....	.....	....	......	......	....	343.860	309.640	34.220	....	....	1.094	.....	Check Basin.
100	Phyllis Canal Boise V.........	5-30	1913	3.69	38.3	141.540	42.35	3.342	2.92	420.450	407.970	12.480	5.840	2.174	.839	.5	
101	T. F. S. R. Main Canal........	7-9	1913	....	.....	....	......	......	....	476.030	447.850	28.180	....	....	.901	.....	Check Basin.
102	T. F. High Line Canal........	7-26	1912	4.94	53.5	264.700	57.00	4.640	2.88	759.620	763.630	—4.010	2.180	—1.840	—.528	—.2	Gain.
103	T. F. High Line Canal........	7-26	1912	5.07	56.7	287.600	61.40	4.690	2.70	783.000	772.650	10.350	2.260	4.580	1.221	.6	
104	T. F. High Line Canal........	7-26	1912	5.48	53.0	290.500	58.90	4.930	2.74	788.360	801.040	—12.680	2.140	—5.925	—1.647	—.8	Gain.
105	T. F. High Line Canal........	7-26	1912	5.55	57.0	316.300	62.60	5.050	2.61	832.000	820.900	11.100	2.060	5.390	1.408	.7	
106	T. F. High Line Canal........	7-26	1912	5.31	60.0	318.800	64.80	4.920	2.72	877.000	856.140	20.860	2.940	7.100	1.793	.8	
107	T. F. N. S. Main C., Milner..	8-18	1913	....	.....	....	......	......	....	1615.420	1507.090	108.330	3.410	31.768	....	2.0	Part Jer. Res.
108	T. F. N. S. Main C., Milner..	8-16	1913	....	.....	....	......	......	....	1755.490	1629.370	126.120	5.110	24.681	....	1.4	
109	T. F. N. S. Main C., Milner..	8-16	1913	....	.....	....	......	......	....	1870.490	1762.490	108.000	8.410	12.842	....	0.7	
110	T. F. N. S. Main C., Milner..	8-15	1913	....	.....	....	......	......	....	1889.730	1870.490	19.240	2.750	7.000	....	0.4	
111	T. F. N. S Main C., Milner..	8-14	1913	....	.....	....	......	......	....	2005.620	1889.730	115.890	8.790	13.184	....	0.7	Wilson L. Res.
112	T. F. N. S. Main C., Milner..	8-13	1913	....	.....	....	......	......	....	2378.670	2365.150	13.520	4.390	3.080	....	0.1	
113	Main Canal, T. F. Pro........	7-20	1912	7.53	104.0	783.600	110.50	7.100	3.43	2737.000	2644.000	93.000	5.350	17.260	2.556	.6	
114	Main Canal, T. F. Pro........	7-18	1912	7.72	107.3	828.900	114.30	7.300	3.33	2798.000	2767.600	30.400	6.070	5.010	.718	.2	
115	Main Canal, T. F. Pro........	7-18	1912	7.73	107.5	830.700	114.00	7.300	3.42	2857.000	2830.000	27.000	2.650	10.200	1.464	.4	
116	Dry Creek Res. T. F. Pro.....	7-15	1912	....	.....	....	......	......	....	2934.000	2880.000	54.000	....	....	....	.....	Dry Cr. Res.
117	Main Canal, T. F. Pro........	7-15	1912	8.09	118.0	955.000	123.00	7.800	3.16	3097.000	2949.000	148.000	5.050	29.300	3.905	.9	
118	Main Canal, T. F. Pro........	7-14	1912	8.00	123.0	984.000	129.00	7.600	3.16	3192.000	3025.000	167.000	3.350	50.000	6.338	1.6	Rock Cuts.

Seepage determinations were made during the seasons of both 1912 and 1913. The results secured during both seasons are included in the above table. The results of 1913 served to strengthen but did not materially change the conclusions that had been arrived at following the close of the 1912 investigation. The major factors brought out by the two seasons' investigation are:

1. The great difference that exists in the amounts lost by canals constructed through different types of soil.

2. That farm laterals, carrying one second foot or less are subject to such an abnormal percentage of loss that a great waste takes place from them when they are used for conducting water even for short distances. This shows up the value of rotation, where the necessity of carrying small amounts is eliminated.

3. That certain types of soil have a fairly uniform loss per square foot of canal bed, and that loss in per cent per mile is misleading.

4. That, all other things being equal, canals should be designed with as small a wetted perimeter as possible in comparison to their cross section, or, in other words, as large a hydraulic radius as possible, if seepage is to be reduced to the minimum.

5. That high velocities which erode and scour the banks increase seepage losses.

6. That porous irrigated land above a canal may cause a gain instead of a loss.

7. That all other things being equal, there is less loss where coulees or natural drainageways are used for canals than where constructed canals are used.

8. That a fill or dike usually shows a greater loss than a canal in a normal section.

9. That canals in average South Idaho soil, which is a medium clay loam, should be designed to withstand a loss of from 0.5 to 1.5 cubic feet per square foot of canal bed per twenty-four hours. That 0.5 cubic feet per square foot per day is a safe basis for impervious clay soils, about 1.0 cubic foot per day for medium soils, and from 1.5 to 2.0 cubic feet per square foot per day is a safe basis for somewhat pervious soils.

Canals in gravel, depending upon the porosity of the gravel, should be designed to withstand a loss of from 2.5 to 5.0 cubic feet per square foot of canal bed per twenty-

four hours, though it is probable that lining would be profitable if the higher loss were experienced.

10. That a project having a comparatively long main canal may lose as much as 30 or 40 per cent of the water diverted before it reaches the farms, even in the impervious soils.

FACTS BROUGHT OUT DURING THE INVESTIGATION AND CONCLUSIONS IN REGARD TO DUTY OF WATER.

Scope of Investigation.

It is believed that the Idaho Duty of Water investigation has been the largest and most comprehensive investigation of the kind that has ever been carried on. It is also believed that the data secured, practically all of which is contained in this report, will furnish a reliable basis for the determination of the proper Duty for any irrigation project where similar conditions obtain. The investigations upon which this report is based have covered four seasons, during which time the water used and yield produced has been accurately measured on 529 individual tracts, consisting of a total area of slightly over 3,600 acres. These tracts have included all of the staple crops and soils common to South Idaho. The water diverted and used by seven different canal systems in 1911 and eight different systems in 1912 was measured. Seepage losses have been determined on 118 different sections of different canals with a total lineal length of 287.31 miles. A total area of 16,065.21 acres, including all or part of 26 typical sections has been surveyed for the determination of the waste or non-irrigated acreage. In addition to the foregoing measurements and determinations, a large number of supplementary investigations were made, among which were investigations of the "use" of water: (1) in the Malad Valley, (2) on the Salmon River Project, and (3) in the Boise Valley, and the Use and Duty of Water and cost of pumping under electrically driven pumping plants in the vicinity of Weiser and Payette. The cost of the investigation for the four seasons from its inception in the spring of 1910 up to and including January 1, 1914, was slightly over fifty-five thousand ($55,000.00) dollars.

Factors Which Affect and Determine the Duty of Water.

The investigation as a whole has thrown much new light on the majority of the many phases of irrigation practice, has determined a proper Duty for the common types of soil and kinds of crop, and has pointed out those factors which have the major effect or influence upon, and which determine the Duty of Water for any project.

The factors which have a direct bearing upon, and which determine the Duty, are: (1) Character of soil and subsoil, (2) fertility of the soil, (3) climatic conditions, (4) value of water, (5) diversification of the farm crops, (6) use of rotation and size of irrigation head used, (7) preparation of the land, (8) kind of crop, and other factors of lesser importance.

1. Character of Soil and Subsoil.

The character of the soil and its porosity has more influence upon the Duty of Water than any other one thing. The porosity of the soil seems to be the most important factor and must always be given careful consideration when determining how much water is required for the sufficient irrigation of any soil. Much greater losses are being experienced from deep percolation on irrigated lands than most irrigators realize. These losses have been found to be the most frequent and serious source of loss or waste of irrigation water on all but the most impervious of soils. If land is underlaid with clay or with a tight impervious hard pan there cannot be any serious loss from this source. but in cases where soil is underlaid by a stratum of porous sand or gravel, large losses are quite certain to be experienced. There is no economical method of irrigation that has been yet devised that will reduce the requirements of porous soils to that of the more impervious soils. Porous soils will therefore always require a larger allotment of water than the medium soils.

Moisture moves through soils in all directions by capillarity, the downward movement being assisted by gravity. The rate and extent of the rise or movement of the moisture in the soils depend principally upon the size and arrangement of the soil particles. Where only a reasonable amount of moisture (4 to 6 inches) is forced into soils at each irrigation the majority of it usually rises again to the surface by capillarity as the surface gradually dries out

The coarser the soil particles the shorter will be the distance the moisture can rise, hence, if a soil is porous and consists of rather large particles, greater losses are not only experienced from deep percolation than with the medium soils, but a lesser quantity of that absorbed by the subsoil can be returned to the surface layers by capillary attraction where it can be used by the plant roots. It is therefore very essential, where the highest possible Duty is required, that soils be selected of fine to medium and practically uniform texture to a depth of at least six feet, for if even a comparatively thin layer of coarse porous soil is found underneath the surface it will not only greatly facilitate losses by deep percolation, but will effectually prevent the rise of the water into the surface layer. Where such porous layer exists practically all of the water that penetrates beyond it will be lost to the use of the plants unless the roots penetrate through it.

A tight impervious hard pan through which roots can penetrate, but which effectually cuts off percolation has been found to have a tendency to increase the Duty of Water. Great losses are now being experienced from deep percolation on the gravelly lands of Idaho because of crude methods of irrigation. This has been amply demonstrated by the "tank experiment" on the Bate ranch near Idaho Falls, which is described later in the report. It has been shown conclusively that economic use of water on these porous lands can only be secured by building frequent cross ditches and using such large heads of water that the surface can be flooded over so quickly that excessive loss from deep percolation cannot take place. Too much emphasis cannot be placed upon the necessity and desirability of using large irrigation heads on porous soils, for it is utterly impossible to irrigate them economically or to avoid abnormal deep percolation losses if comparatively small irrigation heads are used. This emphasizes the desirability of rotation systems by means of which large heads can be commanded by the farmers for comparatively short periods. The California irrigators are coping successfully with this problem by proper preparation of their land and the use of irrigation heads of as much as from 20 to 30 second feet. These large heads are used under a strict rotation system, each individual, no matter what the size of his holdings, being compelled to use this amount of water. Heads of

this size are delivered to each user at intervals of from 21 to 30 days throughout the irrigation season, each individual being allowed to retain this head for only 20 to 30 minutes for each acre upon which he pays maintenance. Heads of the above size are very common in both the Sacramento and San Joaquin Valleys, and are perfectly possible and feasible in many parts of Idaho, and until Idaho irrigators are made to realize the economy of both time and water that might be secured by the use of larger irrigation heads for shorter periods the best results can ever be obtained.

Impervious clay and adobe soils usually do not absorb water readily enough, and it is hard to make them absorb a sufficient amount per irrigation to last for any considerable period. This necessitates more frequent irrigation on this type of soil than on the deep medium soils. There is therefore no doubt that a larger percentage of the water applied to impervious soils is lost by evaporation than of that applied to the medium or porous soils. Losses by deep percolation, however, with the more impervious soils are impossible, and it has been found, generally speaking, that, due to the physical impossibility of wasting water by deep percolation on these soils, the saving effected more than offsets the extra evaporation loss which takes place from them, and that in general, less water is required for their efficient irrigation than with any of the porous or mediumly porous soils.

These shallow and impervious soils, however, usually absorb water so slowly and such a small percentage of the amount applied that it is impossible to prevent an undue amount of water from running off of the lands that are being irrigated. This factor must be taken into consideration when allotting water to individuals with impervious or shallow soils. The extra amount of waste water can usually be caught up below the farms, however, and measured out to the neighbors, so that while more water must be delivered to the individuals, a project as a whole will not require any more water than with the medium soils.

2. Fertility of Soils.

The fertility of the soil has been found to have a great influence on the quantity of water required to produce a given crop. This has been proven experimentally by many investigators,* and recently by the Washington and Ne-

* See U. S. Dep. Agr., B. P. I. Bul. No. 284.

braska Experiment Stations, and in a broader and more practical manner the same thing is shown by the present investigation. Professor C. C. Thom, Soil Physicist of the Washington Agricultural College, has demonstrated that plants grown on sterile sand and irrigated with water containing a strong solution of plant food required less than one-half as much water per gram of yield produced as the same required when planted on the same kind of sand, but when irrigated with water containing a weak solution of plant food, and that the water requirements per unit of yield slowly but gradually decreased as the strength of the solution was increased. The Nebraska Experiment Station in Bulletin No. 128 shows conclusively that corn requires far less water per unit of yield on fertile soils than the same crop requires when planted on infertile soils.

The Duty of Water Investigation upon which this report is based has also shown up this factor in a very striking manner. While no experiments were planned and included in the Duty of Water Investigation for the specific purpose of showing a comparison between the requirements of fertile and infertile soils, a careful study of the results secured during the investigation clearly indicates that very fertile soils will always produce more crop with a given amount of water than the soils of poor fertility, and that they require less water and frequently less than one-half as much water for the production of the same crop as do the infertile soils. This fact is clearly shown in the grain curve on page 100 which is given in the early part of this report. Experiments planned especially for the determination of this factor have since been carried on at the Twin Falls Experiment Station of Irrigation Investigations and fully bear out the assertions that have been above made in regard to the performance of crops planted on the more fertile soils. The influence of soil fertility upon water requirements strongly emphasizes the necessity of maintaining high fertility in all irrigated soils, particularly where economy of water is a factor, and helps to explain the decrease in the requirements for water after a project has been irrigated a few years.

3. Climatic Conditions.

The annual precipitation and its seasonal distribution, together with the temperature, humidity and wind move-

ment, all have a very marked and evident effect upon the amount of irrigation water required for crop production on an irrigation project. The effects of these factors are so evident that they will not be discussed in detail in this report.

The investigation has proven conclusively, however, that a light summer rainfall has far less effect upon crop production that has usually been believed. This is accounted for by the fact that the South Idaho atmosphere is normally very dry and the light rains of from one-quarter to one-half inch do not penetrate deeply enough to reach the soil zone occupied by the plant roots and hence evaporate before sufficient time has elapsed for them to be of any material benefit to the crops. In many cases it has been noted that light rains have done positive damage rather than good, for they have effectually destroyed any soil mulch that might have been manufactured to retain the moisture which had been applied to the soil by previous irrigations. The normal precipitation that occurs in Idaho during the irrigation season is so light that the variations of the precipitation between the different localities seem to have practically no effect upon the Duty of Water. The results secured throughout this investigation seem to indicate that the effect of light summer precipitation on the Duty of Water are practically negligible, so far as the water requirements of a project are concerned.

The winter precipitation in Idaho, however, is more of a factor, for it usually furnishes enough moisture to bring the crops up and give them a good start in the spring. If these data are used in determining the Duty for a project where spring crops must be irrigated up, due allowance on account of this factor must be made in the allotment of water for the project.

4. Diversification of Farm Crops.

No two crops have exactly the same water requirements or need the maximum amount of water at the same time during the season. If a farm or an irrigation projeit is devoted to only one crop the maximum demand for water, or in some cases the entire need for the season, occurs during a brief period. In such cases the water supply of a project can rarely be used to advantage, for the major portion of a continuous flow allotment would run to waste outside of this short period. By diversifying the crops on a

farm or a project the need for water will be more constant throughout the season and a higher Duty and Use of Water is thereby secured.

5. Use of Rotation.

The continuous flow method of delivery should give way to the rotation system. Practical irrigators invariably realize that economical irrigation cannot be accomplished with a small irrigation head, for a small stream dwindles away before it has flooded across the field, and is thus more or less ineffective. Large heads, on the other hand, can be forced across a field quickly and made to do thorough irrigation in a much shorter time. Crops do not require continuous irrigation any more than a man requires a continuous drink of water. The results of the investigation have repeatedly proven conclusively that the use of comparatively large heads results in a saving of both time required for the irrigation and the amount of water required by the crops. Large heads are an absolute necessity with porous soils in order to permit flooding of the surface quickly enough to prevent abnormally deep percolation losses. There are but few projects where rotation of water between individuals will not work satisfactorily. This is particularly desirable where a project consists of small holdings with consequent small allotments per unit. Rotation systems, by means of which a farmer can exchange water with neighbors and use larger heads for shorter periods are now being used in several Idaho localities, and the saving of water and the time of the irrigator are very material. An ideal system of rotation requires that water be maintained in the main canals and main laterals continuously, and that the individuals under each lateral should have access to a good sized irrigation head, probably the full flow of the lateral, at intervals not farther apart than every 14 days. The length of time that the user should be allowed to retain the head should be dependent upon the acreage irrigated. It is sometimes rather difficult to inaugurate rotation systems in localities where the irrigators are unfamiliar with the benefits of such a system, but a locality has never come under the observation of the author where an efficient rotation system has been in use for two years in which the irrigators desired to go back to the old continuous flow system of delivery.

6. Preparation of the Land.

An even application of irrigation water to all parts of a field cannot be secured with rough, uneven, or improperly leveled land. It is therefore apparent that a maximum crop cannot be secured on land that is rough and improperly leveled. The value of proper leveling and the effect of improper preparation on the Duty of Water is so evident that they will not be discussed in this report. Neither will space permit of an extended discussion on the proper methods of preparing land.

Generally speaking the land should be so leveled that uniform application and penetration of the water can be secured. In order to obtain the above water should never be flooded too far between cross ditches. From 300 to 600 feet, depending upon the porosity and topography of the land, is usually about the right distance.

7. Kind of Crop.

The kind of crop, whether cultivated or uncultivated and the length of season that it requires water, have a very direct bearing upon the amount required. Alfalfa requires water from early spring until late fall, as do the clovers and pasture grasses, and has been found to require nearly twice as much water during the irrigation season as the spring or winter grains, which require it for but a comparatively short season. Alfalfa has shown a decided tendency throughout the investigation to produce the most crop where the most water has been applied. It has been made plain that water should never be left standing on alfalfa more than an hour or two if the best results are to be obtained. No more should be applied at an irrigation than the soil will readily absorb. Where the above method of irrigating alfalfa is followed it has been found almost impossible to reduce the yield by applying too much water. The yield produced, however, is in but few cases proportional to the amount of water applied, and it is doubted whether or not it will ever be found feasible to apply more than 3 acre feet per acre to alfalfa or pasture on the medium clay loam soils.

The investigation has proven that grains and potatoes can very easily be over-irrigated. Where abnormal amounts have been applied to grains the yields have always been materially reduced. By far the larger number of the experiments included in the investigation have been

carried on with the spring and winter grains, and these have proven that there is no doubt but that it will rarely be profitable to apply more than one and one-half acre feet per acre to grains. The above applies to the medium or clay loam soils only. Where grains are planted on fertile soils less than the above amount may be required. Where as much as 3 acre feet per acre have ben applied to spring grains at the Gooding Experiment Station the yields have been repeatedly reduced to that which was produced on adjoining plots where no irrigation water was applied, while the maximum yield was produced with approximately one and one-half acre feet per acre.

A cultivated crop such as corn, garden or orchard that can be cultivated between the rows will require, all other things being equal, considerably less water than an uncultivated crop on account of the decreased evaporation losses induced by the cultivation.

The experiment on the Dunlap orchard, which was carried on during the years of 1911, 1912, and 1913, near Twin Falls, is striking proof of the great saving of moisture that can be made by properly cultivating the surface soil. This orchard was thoroughly clean cultivated and made to all appearances a maximum growth and crop of fruit, yet it received only a total of approximately 0.75 acre feet per acre during the three seasons, 1911 to 1913 inclusive. This experiment was carefully conducted and shows conclusively that the methods used by the Southern California walnut, orange, and lemon growers for the conservation of moisture by thorough surface cultivation will be very effective if carried out in Idaho, and that orchards, if planted on a deep soil of medium texture, will require very small amounts of irrigation water for at least the first 10 years of their growth. The Dunlap orchard was seven years old and produced 300 boxes of excellent fruit per acre during the last year of the experiment, with a total application of 0.75 of an acre foot per acre in three years, with an average annual rainfall of approximately 12 inches. This performance seems to prove that this orchard, no matter what its age, will never require more than 1.5 acre feet per acre during any one season, no matter how large a crop of fruit it can be made to produce. This experiment, and many others included in the investigation, strongly emphasize the value of surface cultivation as a saving of water. Where clover or alfalfa is planted as a

cover crop orchards will require at least as much water as alfalfa when grown for hay.

8. Fall Plowing.

Fall plowing should always be recommended. It loosens up the soil early in the fall and renders it more capable of absorbing winter rains and reduces the run off. The use of fall plowing benefits the soil and irrigator in many ways. The fact that the land is plowed in the fall and ready for crop as soon as it has dried out sufficiently in the spring enables the farmer to plant his crops early and in due time, which he might have been unable to do if the land had to be spring plowed. Fall plowing thus allows the crop to start off early in the spring and permits it to make better use of the winter precipitation, and a greater yield with a less than normal quantity of water is usually secured. The turning up and loosening of the soil in the fall is also a decided advantage, for the extra freezing and thawing that takes place together with the aeration of the soil, sets free an added amount of plant food and makes a larger yield possible, all other things being uniform.

An experiment was carried on at the Gooding Experiment Station during the season of 1911 to determine the effect of fall vs. spring plowing on the Duty of Water and yield produced with the results which are shown in the following table. A study of the table makes it apparent that too much emphasis cannot be placed on the many advantages of fall plowing.

Results of Fall versus Spring Plowing Experiment, Gooding Experiment Station.

Sub-plot No.	Area in acres	Treatment of sub-plot	Depth of water applied	Yield of grain		Weight of grain per bushel
				Per acre	Per acre foot	
			Feet			
1	.314	Fall plowed minimum irrigation	.376	41.18	109.5	38.0
2	.315	Spring plowed minimum irrigation	.376	32.88	87.5	38.0
3	.314	Fall plowed average irrigation	.962	43.65	45.5	41.0
4	.314	Spring plowed average irrigation	.962	39 77	41.4	41.0
5	.304	Fall plowed maximum irrigation	1 533	47.54	31.0	42.0
6	.305	Spring plowed maximum irrigation	1.533	45.26	29.5	42.0

OTHER FACTORS WHICH HAVE A BEARING ON DUTY OF WATER AND IRRIGATION IN GENERAL.

Length of Season.

The length of the irrigation season is in many cases fixed

by statute, but the true length of the season or the length of time that crops actually require water is a much mooted question. Many canals are required to run water throughout practically the entire year for domestic purposes and stock water, but the number of days that such canals run water, or the amount of water they divert at such times does not furnish an accurate idea of the water requirements of the crops under them. The Duty of Water Investigation, as carried on, however, throws much new light upon this subject, for in the main only the amounts actually applied to the crops have been considered. In order to furnish a sound basis in regard to the proper length of the irrigation season under average South Idaho conditions, the number of days that elapsed between the date of beginning the first irrigation and the end of the last irrigation of the season of all of the individual tracts included in this investigation is shown in the following table. There has been nothing added either at the beginning or end of the irrigation season for stock water, and the table should be found very dependable as the totals given show the true length of the season that crops require water under Idaho conditions.

Table Showing Average Length of Irrigation Season of Plots Included in the Four Years' Duty of Water Investigation.

Crop	Year	Total No. of plots considered	Average No. of irrigations	No. having one irrigation only	Average length of irrigation *season, days	Maximum length of irrigation season, days	Average dates of irrigation	
							First irrigation	Last irrigation
Grains	1910	76	3.6	3	46.0	87	May 27	July 16
Alfalfa and Clover	1910	27	4.7	0	95.4	144	May 12	Aug. 12
Grains	1911	96	2.1	17	35.5	64	June 13	July 19
Alfalfa and Clover	1911	34	6.1	1	111.4	142	May 14	Sept. 2
Grains	1912	60	3.7	10	39.7	61	June 9	July 18
Alfalfa and Clover	1912	25	5.6	0	87.3	123	May 23	Aug. 18
Grains	1913	66	3.1	8	48.9	110	June 5	July 23
Alfalfa and Clover	1913	15	5.1	0	96.5	119	May 16	Aug. 20

*Exclusive of plots having one irrigation only.

Proper Amount to Apply per Irrigation.

A study of the tables included in this report shows that the amounts that have been applied to the various tracts per irrigation have varied widely. It is not uncommon to find soils that are so impervious that they will barely absorb 0.1 to 0.15 feet in depth per irrigation, on the one hand, or soils so porous that they can be made to absorb

from 1 to 3 feet in depth per irrigation on the other hand. The investigation has made it plain that from 0.1 to 0.2 feet per irrigation is rather insufficient if economy of water is desired, for the moisture forced into the soil does not last long enough between irrigations, thus necessitating more irrigations per season. As an unavoidable loss from evaporation always occurs at each irrigation it is desirable to apply as few irrigations during the season as will be required to maintain a sufficiently high moisture content in the soil for good plant growth. Impervious soil can usually be improved by the addition of manure or the plowing under of alfalfa which incorporates more humus into the soil and changes its nature, after which it will not only absorb water more readily but will retain it longer. It is a singular coincidence that the same process which renders impervious soils more porous, also renders porous soils more impervious, for the addition of humus, either decomposed or otherwise, tends to fill up the excessive amount of pore spaces and renders this soil less porous.

The results of the investigation indicate that, generally speaking, from 3 to 6 acre inches per application is the correct amount to apply, and that impervious soils should be so manipulated that they can be made to absorb at least the lesser amount, while the porous soils should be so handled by using large irrigation heads that they can be irrigated with not over 6 acre inches per application if economy of water is desired.

The fact that a head of one cubic foot per second delivers almost exactly one acre inch per hour makes it comparatively easy for an irrigator to determine approximately how much water he is applying to his land without any difficult mathematical calculation. It is hardly considered that it will ever be practical to predetermine just how much should be applied per irrigation, and then to apply this amount, no more, but it is believed that intelligent and economical practice demand an approximate knowledge of the amount that is being applied.

LOSSES AND WASTE OF WATER.

The individual irrigator is most concerned with the losses or waste of water that may be experienced from four principal sources: (1) transmission losses, (2) evaporation losses, (3) surface waste, (4) deep percolation waste.

Transmission Losses.

These losses are sometimes far greater than most irrigators realize. The seepage data contained in this report clearly show that the transmission losses of an irrigation project between the point of diversion in the stream and the point where it is delivered to the farmer may range from 10 to as high as 50 per cent. Where storage reservoirs are included as part of a project the losses experienced before it is delivered to the farmer may be still greater and total as much as 75 per cent of the amount diverted. The irrigator himself is usually most concerned with the transmission loss in his own individual supply ditch which carries the water from the point of delivery to the land. These supply ditches usually average from one-quarter to one-half mile in length and where one second foot or less is carried the losses in them may amount to as much as 20 to 30 per cent per mile, but 10 per cent per mile would be a fair average for the medium soils. The data included in this report emphasize the desirability of short canals, and that even these should be well constructed through material of a rather impervious nature

Evaporation Losses.

Of evaporation losses those from the irrigated fields are the ones which principally concern the irrigator. These are more or less of a constant and represent a loss that is rather hard to overcome, for the majority of the evaporation losses from the fields take place within 48 hours after irrigation water is applied and before cultivation of the surface to reduce the losses can take place. Supplementary investigations of evaporation loss at the Gooding and Twin Falls Experiment Stations show that where 2 acre feet per acre is used during the season, the same having been applied in from four to six equal irrigations, from six to nine acre inches of it are almost invariably evaporated into the atmosphere, without having transpired through the plants. The high and almost unavoidable loss from evaporation, a large portion of which takes place within three days after application, emphasizes the desirability of applying as few irrigations as possible. Investigations* made by the Irrigation Investigations Department show that the evaporation loss from soils may be materially reduced, (1) by applying the water in rather deep furrows, and (2) by the maintenance of an efficient dust mulch on the surface. This, of course, will apply more

* See Office of Experiment Stations Bulletin No. 248.

particularly to orchards and other clean cultivated crops. The water requirements of alfalfa fields can be materially reduced by disking in the late fall or early spring. This manufactures a sort of loose non-conducting layer on the surface and thereby decreases evaporation, and at the same time renders the surface so much looser that it will absorb more of the moisture which is received through natural precipitation.

Surface Waste.

Many theoretical irrigators or those unfamiliar with Idaho conditions maintain that the farmers should so prepare their fields and so handle their water that no surface waste be allowed to run off. This, however, is not feasible in Idaho at the present time if the value of labor, land, water and crops produced be taken into consideration, and an average irrigator is surely justified in allowing a small per cent of waste providing the same cannot be economically prevented. It is believed that the average waste that has taken place from the individual fields included in this investigation are fair and normal, and that they approximately equal those that may be expected in average irrigation practice in this State. The following table has been compiled in order to show the average waste that has taken place from the tracts included in the investigation, the percentages given being based on quantity of water delivered to the land.

Percentage Wasted of Total Amount Applied.

Crop	Class of soil	Number of irrigations	Percentage of waste		
			Maximum	Minimum	Average
Alfalfa	Clay loam	302	55.7	0.0	19 1
Grain	Clay loam	291	83.3	0.0	25.3
Alfalfa	Gravelly	147	24.8	0.0	1.8
Grain	Gravelly	122	31.4	0.0	2.3

This table gives the average waste from several hundred of the individual tracts that were included in the Duty of Water investigation during the 4 years, the soils and crops being divided into two classes for convenience and ready comparison. The table shows that over one-half of the water applied to grain and alfalfa on clay loam soils is sometimes wasted, and that the average amount wasted of the total amount applied was 25.3 per cent for grain and 19.1 per cent for alfalfa. While the above percentage

of waste may seem high to many, the results of the investigation have shown them to be a fair average. The above figures, however, are based on the result from single fields, and irrigators should not be allowed to waste this percentage from their entire holdings. Their irrigation systems should be so laid out that as much as possible of the waste water could be caught up and used over again on one or more fields before it is finally allowed to be wasted off the farm. It is safe to assume that the average farms of Idaho could be so laid out that waste would not run directly off of the farm from over one-quarter its area. Rather steep farms of small area would naturally waste more water, all other conditions being uniform, than the large flat farms with the more porous soil. Under normal Idaho conditions, however, it is believed that all water contracts should provide for a sufficient delivery over and above the actual water requirements of the soils and crops so that the irrigator might be allowed to waste a small amount, probably between seven and one-half and twelve and one-half per cent of the amount delivered to him, and still retain sufficient for his crop needs.

This is not a very serious factor when a whole project is taken into consideration and no large allowance would have to be made for it, for a large amount of all of the waste water can usually be caught up by the lower laterals and used over again. A larger amount of the waste could be caught up and reused on the larger projects than could be done on the smaller projects. This factor is one that must not be overlooked when designing irrigation projects. All measurements tabulated in this report, with but few exceptions, are those of the actual amounts retained upon the fields in question, and if these measurements are used in alloting water to a new project care must be used to make a reasonable allowance for the unavoidable waste that each individual farmer's water is subject to.

Deep Percolation Loss.

The abnormal amounts that were applied to some of the tracts included in the investigation indicated even as early as the first year of the investigation that the losses from deep percolation were far greater than most irrigators realize. This seemed true, for it hardly seemed possible that alfalfa or other crops could utilize and transpire any more water on porous soils that was required for the same production of the same crop on the medium soils. The

rapid rise of the water in wells during the irrigation season in the near proximity of the lands irrigated demonstrated that such large losses were taking place from this source that it was decided to conduct a simple tank experiment in order to show just what these losses amounted to and whether or not the crops themselves on the porous soils actually required any more water than those planted on the impervious soils.

A tank 2 feet in diameter and 6 feet deep was constructed and installed in the gravelly soil adjacent to one of the experimental plots on the Bate farm in the vicinity of Rigby. This tank was buried in the soil in an upright position with the top flush with the surface and was carefully filled with soil in as near its normal and original position as the same could be placed. The tank was water tight with the exception of one place in the bottom which terminated in a three-quarter inch galvanized iron pipe which led to a tub in a curbed pit several feet away. Alfalfa was planted on the tank and the tank was irrigated during one entire season by applying the same amount to it that was applied to the experimental tract and also to the farmer himself. Seven irrigations, totaling 6.6 feet in depth, were applied to the experimental tract and also to the tank. The alfalfa grew luxuriantly throughout the season, showing that sufficient moisture was retained in the 6 feet of soil of the tank and an equivalent of a depth of 5.5 feet, or 83.5 per cent of the total amount applied, was caught in the tub in the curbed pit, having precolated from the tank.

Mathematical calculation showed that the tank retained an average of only approximately .15 feet in depth at each irrigation. The experiment was continued during the following year, that of 1912, by irrigating the alfalfa in the tank every time it needed water with .15 feet in depth per irrigation. It was found that ten irrigations were required during the season, representing a total application to the tank of 1.5 feet, there having been only a small trace of percolation from it. The alfalfa grew luxuriantly through the season, was cut, thoroughly cured and weighed, and it was found that the hay which grew upon the tank yielded at the rate of 7.15 tons per acre, which proved quite conclusively that the soil in the tank had sufficient irrigation for the production of a profitable crop.

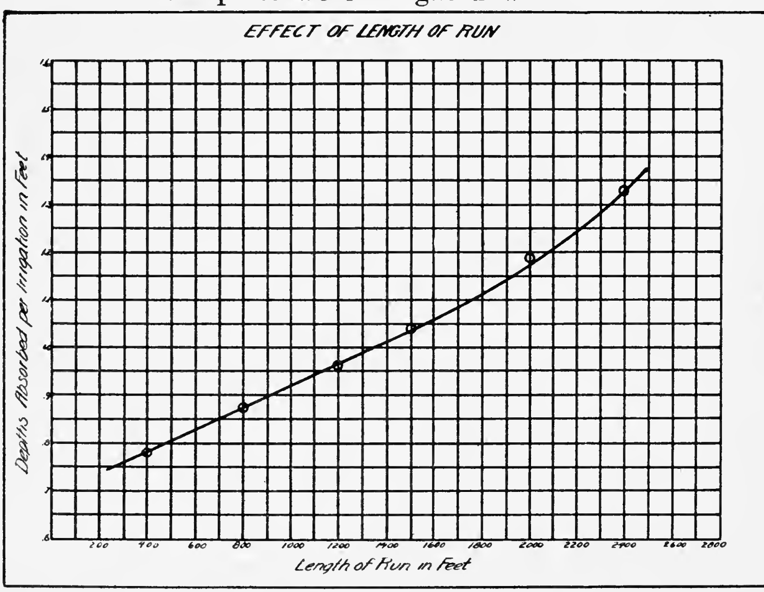
In view of the above and other observations throughout the investigatin there is no doubt in the mind of the author but that an application of 6 acre inches per irrigation to the most porous of soils, which is probably the least amount that can be evenly applied under present practice, will last fully as long between irrigations and grow just as much crop as if from one to two acre feet per irrigation are applied. The only known practical means of irrigating porous soils so as to eliminate as much as possible of the needless deep percolation loss is to prepare these lands for irrigation with the border system into rather narrow lands of reasonable length, say not over 40 feet wide and 300 feet long, and irrigate them with large irrigation heads of from 5 to 10 second feet. On all but the most porous of land this type of a system and size of irrigation head will successfully and economically irrigate the lands with an average application of not over 6 acre inches per irrigation.

From the above discussion of the losses and wastes to which irrigation water is subject it will be seen that in abnormal cases where a large amount of transmission loss, evaporation loss, surface waste and deep percolation waste are experienced, only a very small amount of the water diverted, and probably not over 10 per cent, can be used beneficially by the plants. It is very probable that even with the very best of conditions not over 40 per cent of the water actually diverted from a river or source of supply is, or can be, used beneficially by the plants. The above discussions are given so much in detail with the hope that they will demonstrate to the reader that the amount of loss to which water is subject, rather than the actual requirements of the crops, are the real factors which have fixed the water requirements of a project in the past, and with the idea that they will furnish information by means of which the abnormal losses that are not being experienced in some localities can be reduced.

EFFECT OF LENGTH OF RUN ON DUTY OF WATER.

Water should never be flooded too far or be run in corrugations of too great a length between cross ditches on any class of soil. Where water is run too far between cross ditches even application is not obtained. Too much is usually absorbed on the upper end of the field near the supply

ditch, or too little at the lower end near the waste ditch. This is particularly true with coarse porous soils, there usually being an abnormal amount of deep percolation waste experienced if water is left run long enough to thoroughly irrigate the lower end of the fields. It is concluded from a study of the results secured in the entire investigation that it is never feasible to run water between cross ditches a greater distance than from 300 to 600 feet, depending upon the nature of the crop, the topography of the land, the size of irrigation head used, and the porosity of the soil. A series of experiments were conducted on the porous soils in the vicinity of Rigby for the determination of the effect of length of run upon the amount required per irrigation. It was found that an application of from four to nine acre inches per irrigation lasted fully as long between irrigations and gave equal results with the larger applications, and that the farther water was flooded the greater the amount that was required per application. The soils under consideration were very porous and gravelly and the following curve, based on the results secured from 20 different plots of varying lengths, shows very conclusively that the amount required per irrigation and per season increases very rapidly as the length of the run is increased. These plots were irrigated with heads of from



CURVE SHOWING EFFECT OF LENGTH OF RUN UPON DUTY OF WATER.

3 to 5 second feet, and were only fairly well prepared for irrigation.

EFFECT OF TOPOGRAPHY ON DUTY OF WATER.

It has been found, all other things being equal, that while steep slopes and rough topography in general affect the amount that must be delivered to the individuals who are farming the land, the crops grown on the rough or steep land do not actually require any more moisture than where grown on level land. A larger amount of waste water is unavoidable, however, where steep slopes are irrigated, and a consequent greater amount must be delivered to the irrigators where these lands exist. Poorly prepared land absorbs somewhat more water than where well prepared, for the low spots become over saturated if water is held on long enough to wet up the high spots. The greater portion of the amount that is wasted from the lands over and above the amount retained, if the system is well designed, can usually be caught up and measured out to other customers, in which case a project as a whole will require but little more water if the lands are steep but well prepared than it would if the farms had only a small or medium slope.

EFFECT OF SIZE OF IRRIGATION HEAD.

Where the individual irrigators are able to command irrigation heads of rather large size, from two to ten second feet, their actual requirements in acre feet per acre per season are usually materially reduced over the requirements where the small but continuous flow allotments are used. The effect of a large irrigation head is practically opposite to that of a long run between cross ditches. The larger the head used or the shorter the distance betweeen cross ditches, the less the net water requirements will be during the season. The ability to command a large irrigation head has many advantages, the principal ones among them being the saving of water and time that are required for irrigation. The savings that are effected by the use of large heads are more material where porous soils exist, for the lands can be flooded so quickly that abnormal losses from deep percolation are eliminated. The ability to command large irrigation heads usually necessitates a rotation system, where the water is used not to exceed from

one-fourth to one-tenth of the time on any one farm. This allows plenty of opportunity for other necessary farm work and permits the irrigator to give his undivided attention to the irrigation water while the same is available, which careful attention in itself invariably results in a material saving of water. The value of an efficient system of rotation and the ability to command a comparatively large head of water cannot be overestimated. Rotation systems however, in order to be of the greatest possible value, should be somewhat flexible. Few farmers under the same project, or even under the same lateral, have the same types of soil, the same crop, or even the same areas, and the systems of rotation that seem to give the best satisfaction are usually those where a continuous flow is maintained in the main laterals and the farmers under each lateral are allowed to work out the rotation system best adapted to their individual needs. The kinds of crop should determine the interval between irrigations, and each user should be allowed to control the entire flow of the lateral at intervals of from 10 to 14 days, the length of time he is allowed to retain water at each interval being dependent upon the number of acres owned.

EFFECT OF INDIFFERENCE OF WATER USERS.

There are many factors which have a decided influence upon the Duty of Water, but in actual practice the value of the irrigation water may have a greater inflence than all other factors together. Where water is very valuable and is settled for on a basis of a certain rate per acre foot by the person who uses it, a very high Duty is invariably secured, no matter what may be the climate, the class of soil or the crop grown. Under the above conditions all irrigators soon become skillful. Continuous flow allotments which are paid for on a flat basis per acre for the season are the greatest enemy to a high Duty of Water. There are but few other commodities that are delivered to the consumers on this basis, and irrigation water should not be, for the flat rate of payment, independent of the amount used, places a premium on carelessness and waste. Without a strong underlying incentive to save water a high Duty can never be secured on any project. It is believed that the acre foot should be made the unit of measurement and the basis of all contracts and decrees, and that the

annual maintenance of all projects should be based upon the acre feet actually used during the season by the individuals. It is believed that the adoption of the acre foot as a basis of all water rights and the sale or delivery of water by the acre foot would go further toward increasing the Duty without decreasing crop production than any other feature that could be inaugurated at this time.

EFFECT OF CONTINUOUS FLOW ALLOTMENTS.

The effect of continuous flow allotments is also to place a premium upon waste and the careless use of water. There is no doubt but that water contracts calling for a uniform continuous flow are radically and fundamentally wrong. No matter how much a user may waste one day he is entitled to and sure of the same amount the following and succeeding days. The adoption of a quantity basis such as a Duty expressed in acre feet per acre would not jeopardize old water contracts or priorities, for the water right holders could be allowed quantities equivalent to the continuous flow to which they are now entitled. If water was distributed on a quantity basis, measuring devices would be installed and the water would not be permitted to run to waste between irrigations as is usual where the uniform continuous flow method of delivery is in vogue. The users would fear lest their season's allotment be exhausted before the end of the season and would inaugurate rotation systems, which in themselves would increase the Duty very materially. They would then call for only enough water for the sufficient irrigation of their crops each time, after which it would be to their own interest to see that the headgate be shut down and that none be let run to waste between irrigations. The adoption of such a system as above outlined would work out to the best advantage with storage systems.

EFFECT OF TIME OF APPLICATION.

The stage of growth at which irrigation water is applied, particularly with the grains, is found to have almost as much effect on the crop produced as the total amount of water applied. It has been found that one good irrigation at a critical period of the plant's growth is worth as much as two or three at other stages of its growth. The time of irrigation does not seem to have so much effect

upon alfalfa and clover. The effect of time of application upon the yield of grain produced has been eliminated from the present investigation as much as possible by applying irrigations on the comparable plots at as near the same time as possible.

This factor has been shown to be so important that a Federal Experiment Station has been started at Twin Falls for the sole and specific purpose of determining at which stage of growth the various crops should be irrigated in order to give the best results. The investigation as a whole, however, has thrown considerable light on this subject. In a general way it seems best to irrigate alfalfa and clover before and after each cutting, and as near before the time of cutting as will allow the surface soil time to dry out sufficient for the cutting and curing of the crop. Alfalfa, throughout the investigation, has been inclined to produce the most crop where the most water was applied, and it seems best to keep a medium but uniform content of moisture in the soil of an alfalfa field throughout the irrigation season. Only as much as will be promptly absorbed, however, should be applied, for water should never be allowed to stand on alfalfa for any length of time. With the grains the maximum amount of water seems to be required at the booting, jointing, and soft dough stages in order to properly fill the kernels. Grain should never be allowed to suffer for water during the blooming or soft dough stages, or shriveled grain will result. Potatoes seem to require a medium but uniform moisture content in the soil from the time the plants appear above ground until just before maturity, when the water should be turned off in order that the tubers may ripen properly. Potatoes require practically the same amount of moisture as grains, which is to all intents and purposes about one-half the amount that is required by alfalfa, clover, and pasture, on the same soil. Potatoes should never be allowed to dry out until maturity nor should they be flooded, for the soil around the tubers in the hills should never be saturated. They should be irrigated with a rather deep furrow between the rows, in which case only a sufficient amount for good growth will reach the tubers through capillary attraction. Pastures require light but frequent applications of water and should never be allowed to dry out or suffer for lack of water if a maximum yield is to be secured. Orchards require but

little water during the early part of the season if the soil is thoroughly cultivated. Bearing orchards require the majority of the season's supply during the middle and latter part of the season. Where large areas of orchards are found a larger percentage of the season's supply will be needed during August and September than is shown by the tables contained in this report.

SUMMATION OF LOSSES TO WHICH WATER OF A PROJECT MAY BE SUBJECT.

The investigation has shown:

(1) That seepage and evaporation losses in the main canal of a project may range from 10 to 50 per cent, and that the average for most projects is fully 30 per cent of the total amount of water diverted.

(2) That the seepage and evaporation losses in the internal lateral system of a project range from 5 to 15 per cent with a probable average of 7.5 per cent.

(3) That the deep percolation losses on the farm range from 10 to 80 per cent and will probably average 20 per cent.

(4) That the surface waste from a farm will range from 5 to 50 per cent of the amount delivered, and should average approximately 12.5 per cent.

(5) That the evaporation loss of the amount retained on the farm will range from 6 to 12 acre inches, or from 10 to 50 per cent of the amount delivered.

It is hardly probable that the water which is delivered to any particular individual on any particular project will suffer the maximum loss from each and all of the above sources, though it is entirely possible. A careful study of the above summary shows that but an exceedingly small part of the amount that is diverted at the head of the main canal is, or ever can be, absorbed and transpired by the plants. The above losses represent actual determinations for the most part, and while they can never all be eliminated, a study of the above tabulation shows strikingly that the present average irrigation practice is indeed a very wasteful one.

The losses in the internal lateral system and in the

main canal of a project might be almost wholly eliminated, however, in cases where the saving would justify the expense, by lining all canals with concrete or by conveying the water in pipes. Deep percolation losses and surface waste from the farm might also be almost entirely eliminated by careful preparation of the land and skillful application of the water. Evaporation loss that takes place from the fields, however, can never be entirely eliminated, but may be materially reduced by the application of water in deep furrows, and thorough surface cultivation. The above discussion should clearly indicate that in by far the majority of cases the value of the irrigation water has a greater influence on the Duty than all other factors together, for it is quite plain that the greater part of the water that is now diverted is lost before it can be used by the plants and that most of the losses that irrigation water is now subjected to can be eliminated where the saving will justify the necessary expense. That there is much less water required for the actual use of the plants than most irrigators realize is amply demonstrated by the large yields that are being secured with very small quantities of water in Southern California and other places where water is very valuable. Any one who has studied irrigation conditions elsewhere will be compelled to admit that a large amount of preventable waste is now being experienced in Idaho and other places where water is cheap. Economic conditions do not warrant saving all of this waste today, but there is no doubt but that the time is fast approaching when better systems must be constructed.

PROPER DUTY FOR IDAHO PROJECTS.

The results of the investigation indicate that a normal Idaho project with deep medium clay loam soils should furnish sufficient water so that 2 acre feet can be retained upon each and every irrigated acre during the season. That this amount should be delivered under a rotation system in heads of such size that economical use can be secured, and that where a project is devoted one-half to grain and the other one-half to alfalfa or crops requiring a similar amount, 18.65 per cent of this two acre feet should be delivered during May, 28.42 per cent during June, 32.85 per cent during July, 16.78 per cent during August, and 2.32 per cent during the first one-half of September, there being

but little need for water during the month of April, and practically none after the middle of September. It has been shown that there must be delivered to the farmer approximately 2.25 acre feet per acre at the farm if it has a normal slope, in order for him to retain two acre feet upon the land, but that the amount delivered must be increased where steep slopes are irrigated. The excess that is delivered over and above the two acre feet per acre will be largely caught up in lower laterals and drain ditches, and a considerable part of it can be delivered again to other users.

Where projects consist all or in part of porous soils, or of soils with porous subsoil lying closer to the surface than six feet, more than 2.25 acre feet per acre should be delivered to the consumers, the amount required being largely dependent upon the porosity of the soil.

In a general way the required Duty for a soil can be determined for any crop by determining, (1) how many irrigations the crop will require during the season, and (2) the amount of water the soil will require per irrigation.

In order to illustrate how the data contained in this report can be used for determining the size of a project that can be irrigated from a certain definite water supply, the following purely fictitious project will be used as an example:

Let it be assumed that an earth reservoir can be constructed to impound the total annual run-off of a stream which averages 150,000 acre feet, and that a large body of good deep clay loam soil with an average topography can be irrigated by a main canal 20 miles in length.

There are but little dependable data in existence in regard to reservoir losses. This investigation has not furnished any light on the subject. An annual loss of 20 per cent of the gross amount of the run-off from seepage and evaporation in the reservoir would, however, be the very least loss that it would normally be safe to assume. This would render available 80 per cent of 150,000 acre feet, or 120,000 at the reservoir outlet. Seepage losses in the 20 miles of canal and in the laterals should then be determined by allowing for not less than one cubic foot of loss per day from each square foot of wetted area in the canals and laterals throughout the irrigation season. This would in the above case amount to an additional loss of fully 20 per cent in transmitting the water from the reservoir to the

individual farms, and would allow of a delivery of 96,000 acre feet to the farms. Assuming that the soil was of good character and not inclined to be porous, 2.25 acre feet would be required for delivery to each acre. Ninety-six thousand acre feet would furnish 2.25 acre feet for 42,666 acres. If there was an average of two acre feet retained on each acre, 0.25 acre feet per acre would be wasted or a total of 10,666 acre feet. Fully one-half of this waste should be again caught up and measured out to other consumers and would furnish two acre feet per acre for an additional area of 2,666 acres, making a total net area of 45,332 acres that could actually be irrigated from the water supply. The survey of waste land showed a percentage unirrigated of 8.06. Assuming that 10 per cent of this project would never be irrigated because of roads, both county and private, railroad rights of way, and other unirrigated spots of all kinds, it will be seen that water would be required for but 90 per cent of the gross area of the project. This would increase the 45,332 acres to 50,369 acres as the gross area of the project that could be irrigated under normal conditions by a stream with a gross annual run-off of 150,000 acre feet, provided there was sufficient storage capacity to retain it until needed.

The investigation has demonstrated the adequacy of two acre feet per acre for diversified crops on the better class of soil, but it requires careful husbandry to render this amount adequate, and it seems very evident that but few projects will ever exist in Idaho where an allotment of less than this amount would be justified.

It is believed, however, that the amount of water that will produce the maximum yield of crop on any certain class of soil, is in but few cases the proper and economic Duty. It is very evident, and the author wishes to strongly emphasize the fact, that the cost of land, of water, the value of the crops produced, and the costs of producing them, as well as the amount of water that will produce the largest yield, must all be taken into consideration when determining the Duty for any project.

The largest crop has been produced in many cases where the most water has been applied, but the yield has been in but few cases, proportional to the amount of water required, and in view of this there is no doubt but that, broadly speaking, one would be justified in opening up a project with a higher Duty of water in places where water

is very valuable and land comparatively cheap, than where land is high and water comparatively inexpensive. The allotment of the proper amount of water for an irrigation project, however, is a very serious problem, and one that must be given the most careful consideration, for it is fully as vital to err on the side of too little water as it is on the side of too much water, and vice versa.

GENERAL SUMMARY.

1. The Duty of Water Investigation, of which the preceding pages are a detailed report, has covered four seasons, during which time water has been accurately measured on 529 individual tracts consisting of a total area of slightly over 3,600 acres. These tracts have included all of the staple crops and soils common to South Idaho. The water diverted and used by seven different canal systems in 1911, and eight different systems in 1912 was measured. Seepage losses have been determined on 118 different sections of different canals with a total lineal length of 287.31 miles. A total area of 16,065.21 acres, including all or parts of 26 sections, has been surveyed for the determination of the waste or non-irrigated acreage contained in a project. In addition to the foregoing measurements and determinations a large number of supplementary investigations have been made.

2. The cost of the investigation for the four seasons from its inception in the spring of 1910 up to and including January 1, 1914, was slightly over $55,000.00.

3. The Duty of water depends upon a variety of factors which are in the apparent order of their importance: (1) character of soil and subsoil, (2) fertility of soil, (3) climatic conditions, (4) diversification of farm crops, (5) use of rotation, (6) preparation of the land, (7) kind of crop, (8) fall plowing, and other factors of lesser importance.

4. The following factors and conditions tend to decrease the Duty: (1) porous soil, (2) infertile soil, (3) cheap water, (4) careless use, (5) poorly prepared land, (6) small irrigation heads, (7) poorly constructed leaky ditches, (8) continuous flow method of delivery, (9) lack of cultivation, (10) large acreages of alfalfa and pasture, and other crops with large water requirements.

5. The following factors and conditions tend to increase the Duty: (1) deep soil of fine texture, (2) an

underlying strata of hard pan, (3) expensive water, (4) careful skillful use, (5) well leveled land, (6) large irrigation heads, (7) short runs, (8) use of rotation systems, (9) diversification of crops, (10) well constructed irrigation systems with small transmission losses, (11) fall plowing and intensive surface cultivation, (12) large acreages of winter grain, cultivated crops and orchard, and other crops of low water requirements.

6. The amount of water required by a project depends upon: (1) the Duty of water at the land, (2) losses in reservoirs where water is stored, (3) transmission losses from the point of diversion to the land to be irrigated, and (4) the proportion of a project that is ultimately irrigated.

7. The required duty for a crop on any soil can be roughly determined by ascertaining, (1) how many irrigations the crop will require during the season, and (2) the amount of water the soil will require per irrigation.

8. The Duty for projects planted to diversified crops on the average clay loam soils of South Idaho should be sufficient so that two acre feet per acre can be retained on each irrigated acre.

9. A sufficient quantity should be delivered to each individual over and above the two acre feet so that he may, if unavoidable, waste not to exceed 12.5 per cent of the water delivered to him.

10. Fertile soils require less water for the production of the same crop than infertile soils.

11. A tight impervious soil that roots can penetrate increases the Duty.

12. More water is required where porous subsoils exist.

13. Gravelly soil may require two or more times as much water as the medium soil, the amount required depending upon the porosity of the soil, the distance water is flooded and the preparation of the land for irrigation.

14. As much as 80 per cent of the water applied to gravelly soil is sometimes lost to the use of the crops from deep percolation.

15. Gravelly soils should invariably be irrigated by flooding large heads of water short distances.

16. The light summer rainfall common to South Idaho has but little effect on the amount of irrigation required.

17. Cultivated crops, all other things being equal, require less water than uncultivated crops, as the loss from

evaporation can be reduced by thorough surface cultivation.

18. Fall plowing tends to materially increase production and decrease water requirements.

19. Grains and cultivated crops in general require less irrigation water than the other common crops of South Idaho.

20. Winter grains require less water than spring grains.

21. The time of application has a decided effect upon the yield of grain.

22. Grains require the largest amount of water at the flowering or soft dough stages. Alfalfa, clover and pasture should be kept uniformly moist throughout the season and require almost exactly twice as much water on the same soil as the grains.

23. Alfalfa has a decided tendency to increase in yield as the amount applied is increased until at least as much as four acre feet per acre have been applied.

24. While some crops increase in yield as the amount of water applied is increased, the increase in yield is rarely proportional to the increase required in the amount of water.

25. The average waste from grain fields has been 25.3 per cent and 19.1 per cent from alfalfa. The Duty for a project should be so fixed that 12.5 per cent of the amount delivered to a farm may be wasted.

26. Diversification of crops greatly increase the Duty.

27. Very little water is required for a project either earlier than May or later than August.

28. The average length of the irrigation season for alfalfa for the four years of the investigation was 97.6 days, and 42.5 days for grain.

29. The need for water is not constant during the season for projects with diversified crops. About one per cent of the season's supply is required during April, 18 per cent during May, 28 per cent during June, 32 per cent during July, 16 per cent during August, and about 2.5 per cent during the first half of September, after which there is very little need for water. This is shown in detail by the table on page 103.

30. Over 60 per cent of the total supply for the season is required by a project devoted to diversified crops during the months of June and July. Owing to the large demands

of the crops during these two months but few canals can deliver more than is required during this period.

31. The use of rotation systems and large irrigation heads decrease the net amount of water required during the season.

32. Normal canal systems, particularly where water is inexpensive, divert far more water than is actually required both early and late in the season.

33. The amount of water that will produce the largest yield of a certain crop on a certain soil is not always the economic Duty.

34. The value of land, the cost of water, the value of the crops produced and the cost of producing them, as well as the amount of water that will produce the largest yield, must all be taken into consideration when determining the economic Duty for any project.

35. Sufficient water for the production of profitable and nearly maximum crops must be delivered to the individuals in order that a project may be successful, but a higher Duty is justified in cases where water is very valuable and land comparatively cheap than where water is cheap and the land is valuable.

36. The expression of seepage losses as per cent of loss per mile is misleading.

37. Seepage losses should be expressed as the unit of loss per unit of wetted area of canal bed per unit of time.

38. Evaporation losses from canals are negligible.

39. The percentage of loss is extremely high in small laterals carrying one second foot or less.

40. Losses from canals in medium soil range from 0.5 of a cubic foot to 1.5 cubic feet per square foot of canal bed per 24 hours.

41. Porous irrigated land above a canal may cause it to gain instead of lose.

42. Canals should be laid out through compact soils where possible, and should be designed with as small a wetted perimeter as possible.

43. Ninety per cent of a normal Idaho project is irrigated each year. The total waste and unirrigated areas seldom equal 10 per cent.

44. Where rotation systems are used the interval between rotations should seldom exceed from 10 to 14 days.

45. There are now at least 163 electrically operated pumping plants in the vicinity of Weiser and Payette.

46. The plants tested during 1913 pumped varying amounts of water, the amounts pumped per acre ranging from 0.4 to 5.99 acre feet. The costs of the power for pumping varied from $.54 per acre foot to $6.50, and per acre irrigated from $1.77 to $7.00.

47. There is not sufficient incentive to save water where a flat season rate is paid for power.

48. The investigation indicates that the cost of lifting water over 100 feet with small plants is at present prohibitive.

49. Serious loss and waste of power is now taking place in many instances due to faulty design and cheap careless installation of the plants. Small and medium sized plants should develop efficiencies of at least 50 per cent and only such plants as can be guaranteed to do this or better should be installed.

50. Successful irrigation in Idaho under present economic conditions demands that at least two acre feet per acre be supplied for, and retained upon, each irrigated acre.